National Aeronautics and Space Administration

# Space Launch System Progress Report


**Joan (Jody) A. Singer, SLS Deputy Program Manager**
**Garry M. Lyles, SLS Chief Engineer**
**David E. Beaman, SLS Spacecraft and Payload Integration Manager**
**Jerry R. Cook, Program Planning and Control Manager**
**NASA Space Launch System (SLS)**


*September 2011*

# Agenda

- **SLS Progress**
  - **Jody Singer, SLS Deputy Program Manager**
- SLS Trade Studies and Point of Departure Configuration
  - Garry Lyles, SLS Chief Engineer
- SLS Payload Capability
  - David Beaman, SLS Spacecraft and Payload Integration Manager
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# The NASA Vision

***To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind.***

## *NASA Strategic Goals*

- ✔ *Extend and sustain human activities across the solar system.*
- ✓ Expand scientific understanding of the Earth and the universe in which we live.
- ✓ Create the innovative new space technologies for our exploration, science, and economic future.

  Advance aeronautics research for societal benefit.
- ✓ Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.
- ✓ Share NASA with the public, educators, and students to provide opportunities to participate in our mission, foster innovation, and contribute to a strong national economy.

***SLS Enables NASA's Strategic Goals***

# NASA Authorization Act of 2010

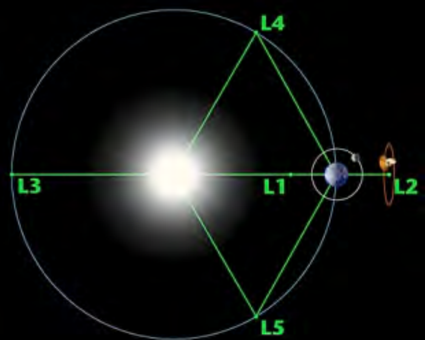
- **The Congress approved and the President signed the National Aeronautics and Space Administration Authorization Act of 2010**
  - Bipartisan support for human exploration beyond low-Earth orbit (LEO)

- **The law authorizes:**
  - Extension of the International Space Station (ISS) until at least 2020
  - Strong support for a commercial space transportation industry
  - **Development of a Multi-Purpose Crew Vehicle and heavy lift launch capabilities**
  - **A "flexible path" approach to space exploration opening up vast opportunities including near-Earth asteroids (NEA) and Mars**
  - New space technology investments to increase the capabilities beyond Earth orbit (BEO)

***This rocket is key to implementing the plan laid out by President Obama and Congress in the bipartisan 2010 NASA Authorization Act.***

*NASA Administrator Charles Bolden*
*September 14, 2011*

# SLS Is Evolvable and Flexible, Providing Capabilities for Potential Missions




**Mars and Its Moons Phobos and Deimos:**

– A premier destination for discovery: Is there life beyond Earth? How did Mars evolve?
– True possibility for extended, even permanent, stays
– Significant opportunities for international collaboration
– Technological driver for space systems

**High-Earth Orbit (HEO)/Geosynchronous-Earth Orbit (GEO)/Lagrange Points:**

– Microgravity destinations beyond LEO
– Opportunities for construction, fueling, and repair of complex in-space systems
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**Earth's Moon:**

– Witness to the birth of the Earth and inner planets
– Has critical resources to sustain humans
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**Near-Earth Asteroids:**

– Compelling science questions: How did the Solar System form? Where did Earth's water and organics come from?
– Planetary defense: Understanding and mitigating the threat of impact
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– Excellent stepping stone for Mars

# Expanding Humanity's Frontiers of Discovery

# Human Exploration Initial Capabilities

- **The Space Launch System (SLS) Program**, managed by the Marshall Space Flight Center (MSFC), will develop the heavy-lift vehicle that will launch the crew vehicle, other modules, and cargo and equipment for exploration missions beyond Earth's orbit. It uses common elements for initial capability and can be evolved as advanced technologies become available, minimizing development costs.

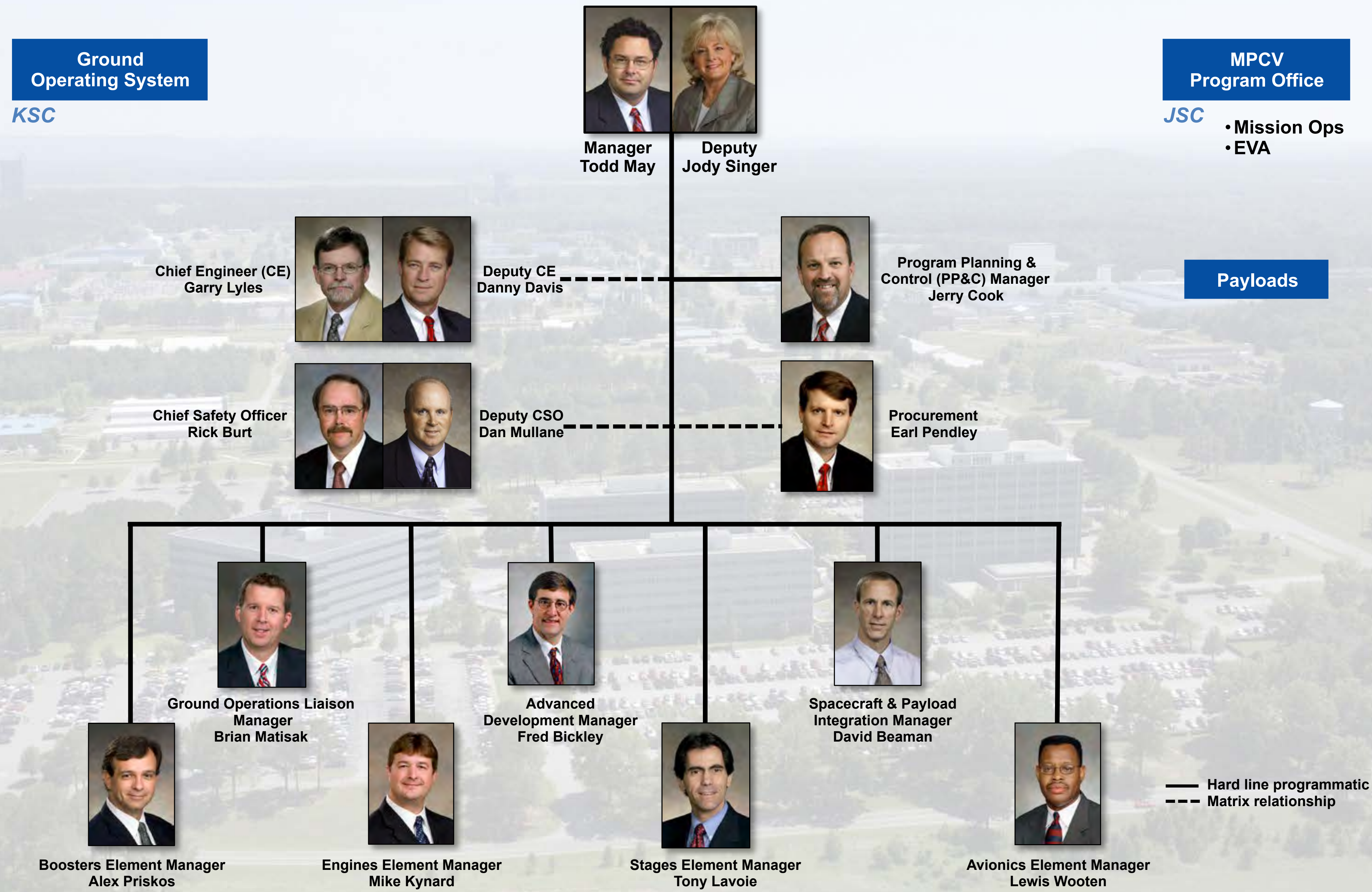
- **The Multi-Purpose Crew Vehicle (MPCV) Program**, managed by the Johnson Space Center (JSC), will develop the spacecraft that will carry the crew to orbit, provide emergency abort capability, sustain the crew while in space, and provide safe reentry from deep space return velocities.

- **The 21st Century Ground Systems Program** will provide launch processing in the Vehicle Assembly Building, which has the unique capability to handle massive launchers. The crawler transporter will move the stacked vehicle to Launch Pad 39B for launching.

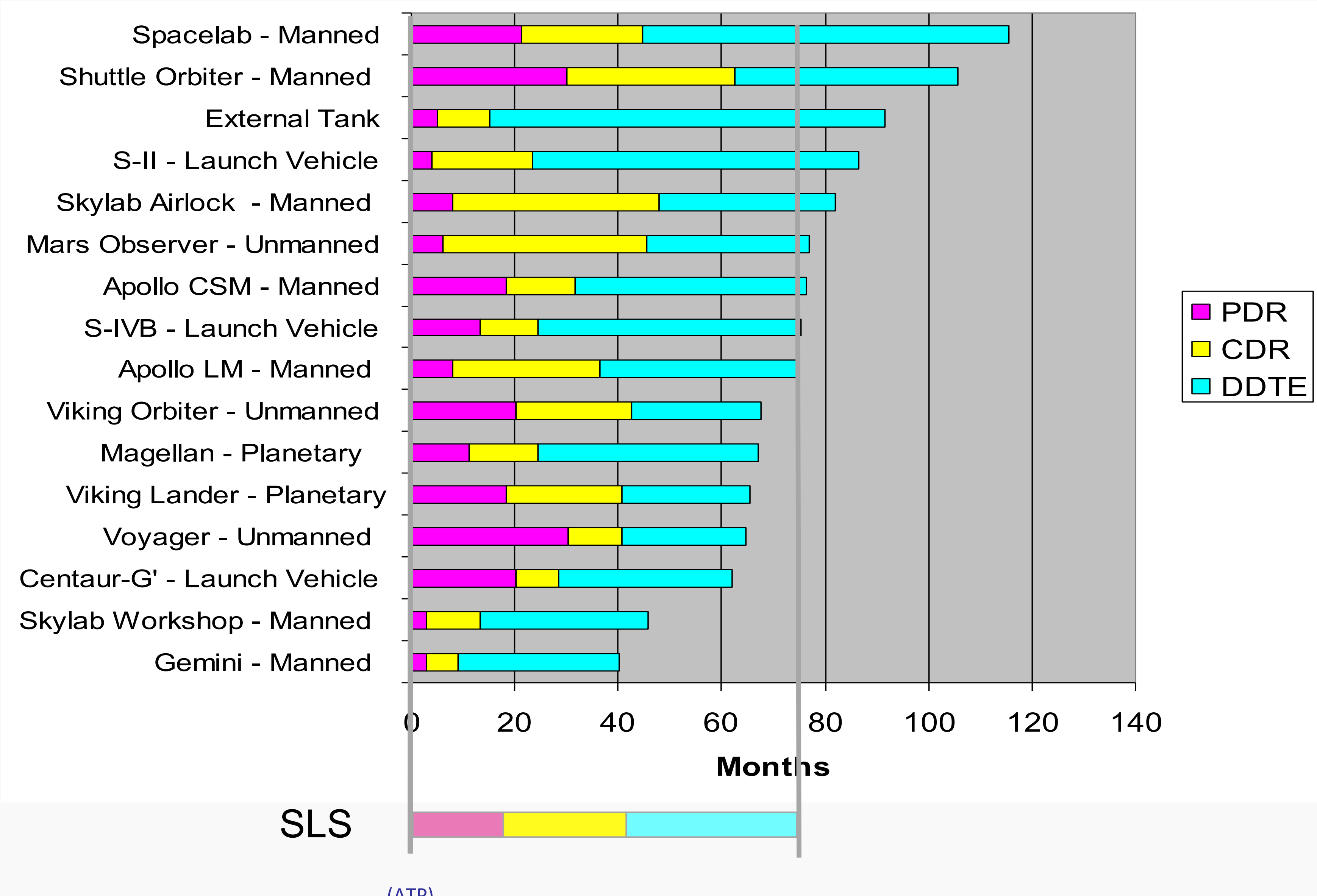
# Timeline and Near-Term Events

| ACTIVITY | 2010 OCT | 2010 NOV | 2010 DEC | 2011 JAN | 2011 FEB | 2011 MAR | 2011 APR | 2011 MAY | 2011 JUN | 2011 JUL | 2011 AUG | 2011 SEPT | 2011 OCT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Human Exploration Capabilities (HEC) Analysis of Alternatives | ■ | | | | | | | | | | | | |
| SLS Planning Team Established | | | ■ | | | | | | | | | | |
| RAC I Briefing | | | | | ■ | | | | | | | | |
| SLS Program Established | | | | | | ■ | | | | | | | |
| HEC Level I Requirements Baselined | | | | | | ■ | | | | | | | |
| SLS MCR | | | | | | ■ | | | | | | | |
| ESD AoA | | | | | | | ■ | | | | | | |
| Broad Agency Announcement (BAA) Final Reports | | | | | | | | ■ | | | | | |
| Acquisition Strategy Meeting (ASM) | | | | | | | | | | | ■ | | |
| Independent Cost Assessment (ICA) Report | | | | | | | | | | | ■ | | |
| MSFC Transition | | | | | | | | | | | | ■ | |
| J-2X Engine Test #5 (50 Sec.) Conducted | | | | | | | | | | | ▼ | | |
| DM-3 Test Firing Conducted | | | | | | | | | | | | ▼ | |
| SLS Announced by Agency | | | | | | | | | | | | ▼ | |
| Conduct PSMs | | | | | | | | | | | | ■ | |
| Industry Day Briefings | | | | | | | | | | | | | |
| SLS Team Formed | | | | | | | | | | | | | ▼ |
| Submit Final Report to Congress | | | | | | | | | | | | | ▼ |
| Check Point Review for SLS SRR | | | | | | | | | | | | | ▼ |

# SLS Program Organization at MSFC



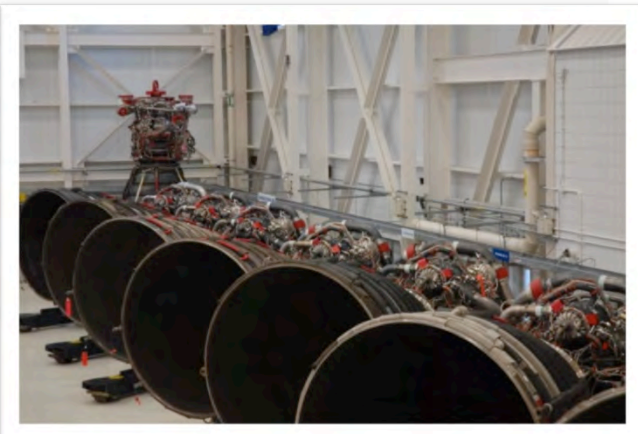
# NASA Program Life Cycles (ATP to First Flight)

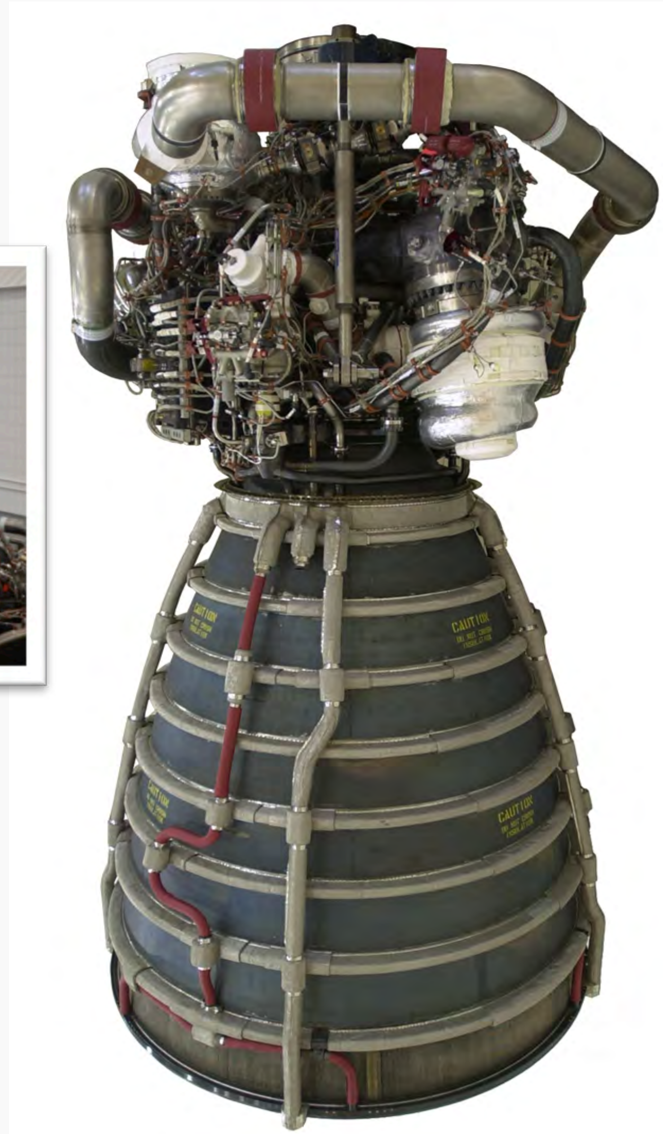



Data Source: SAIC (provided by Uwe Hueter)

# RS-25D Engine

- ♦ **15 Flight Engines**
- ♦ **2 Development Engines**
- ♦ **Additional Spare LRUs**





**High Performance System**
- 492K lbs nominal thrust
- 453 sec Isp (avg. flight derived)

**Operational Capability**
- ~ 67% to 109% throttle range

**Physical Characteristics**
- Weight: 7,750 lbs
- Size: 96” D X 168” L

**Mature Design, Manufacturing and Operational Knowledge Base**
- >1,200,000 sec hot-fire time

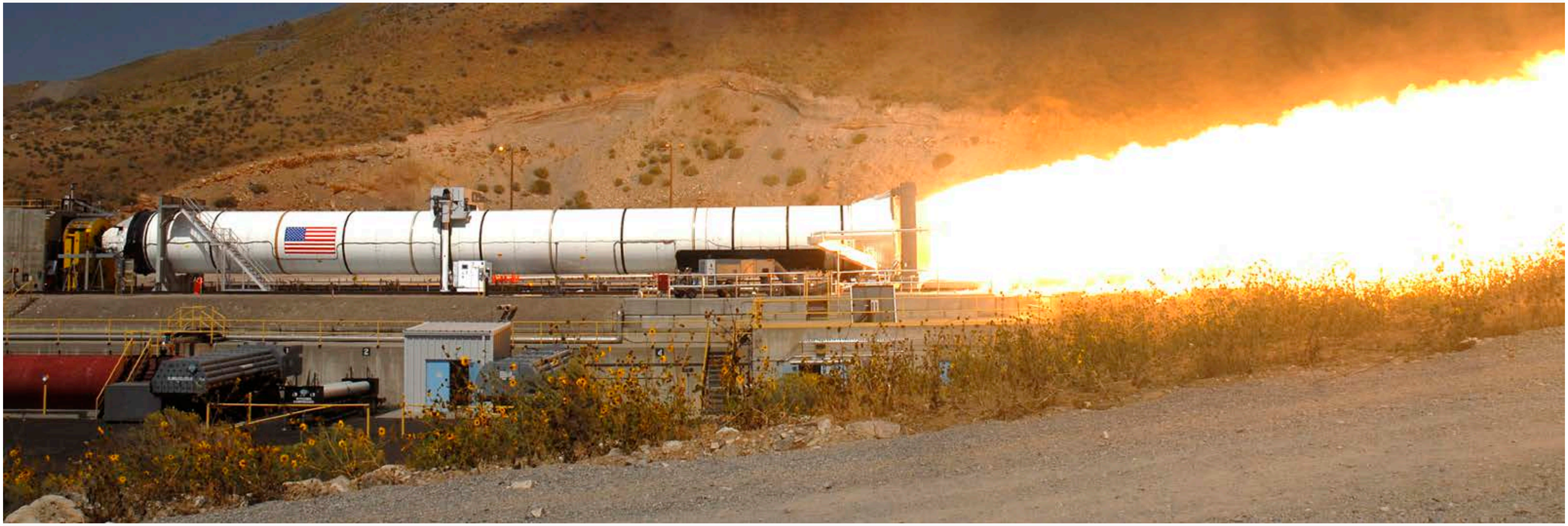
**Catastrophic Failure Risk**
- 1/1956 starts

**Human Rated per Shuttle Program Requirements**

**Significant U.S. Investment in SSME capabilities**

***Utilize existing legacy assets to support early launches***

# Solid Rocket Development Motor 3 (DM-3) Testing



- **DM-3 static test conducted September 8**
  - 37 Objectives assessed with 979 instrumentation channels
  - Propellant Mean Bulk Temperature (PMBT): $90^0$F
  - Insulation weight reduced by approximately 1300 lb (compared to DM-2)
  - Nozzle
    - Composed of ENKA CCP on all components
    - Modified throat contour
    - Modified Aft Exit Cone (AEC)
    - Installation of an AEC severance system for post-test severance

# J-2X 50-Second Engine Test


***The J-2X Upper Stage Engine is in Development Testing***

# Advancing the U.S. Legacy of Human Exploration

# Summary

- SLS Is a National Capability that Empowers Entirely New Exploration Missions
- SLS Program Key Tenets are Safety, Affordability, and Sustainability
- SLS Builds on a Solid Foundation of Current Capabilities to Enable a Fast Start and a Flexible Heavy-Lift Capacity for Missions of National Importance
- The SLS Team has made Significant Progress
- The Road Ahead Promises to be an Exciting Journey for Current and Future Generations

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- SLS Planning

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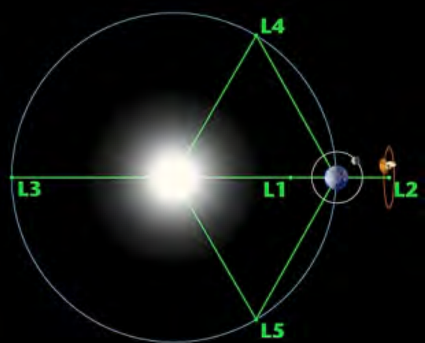


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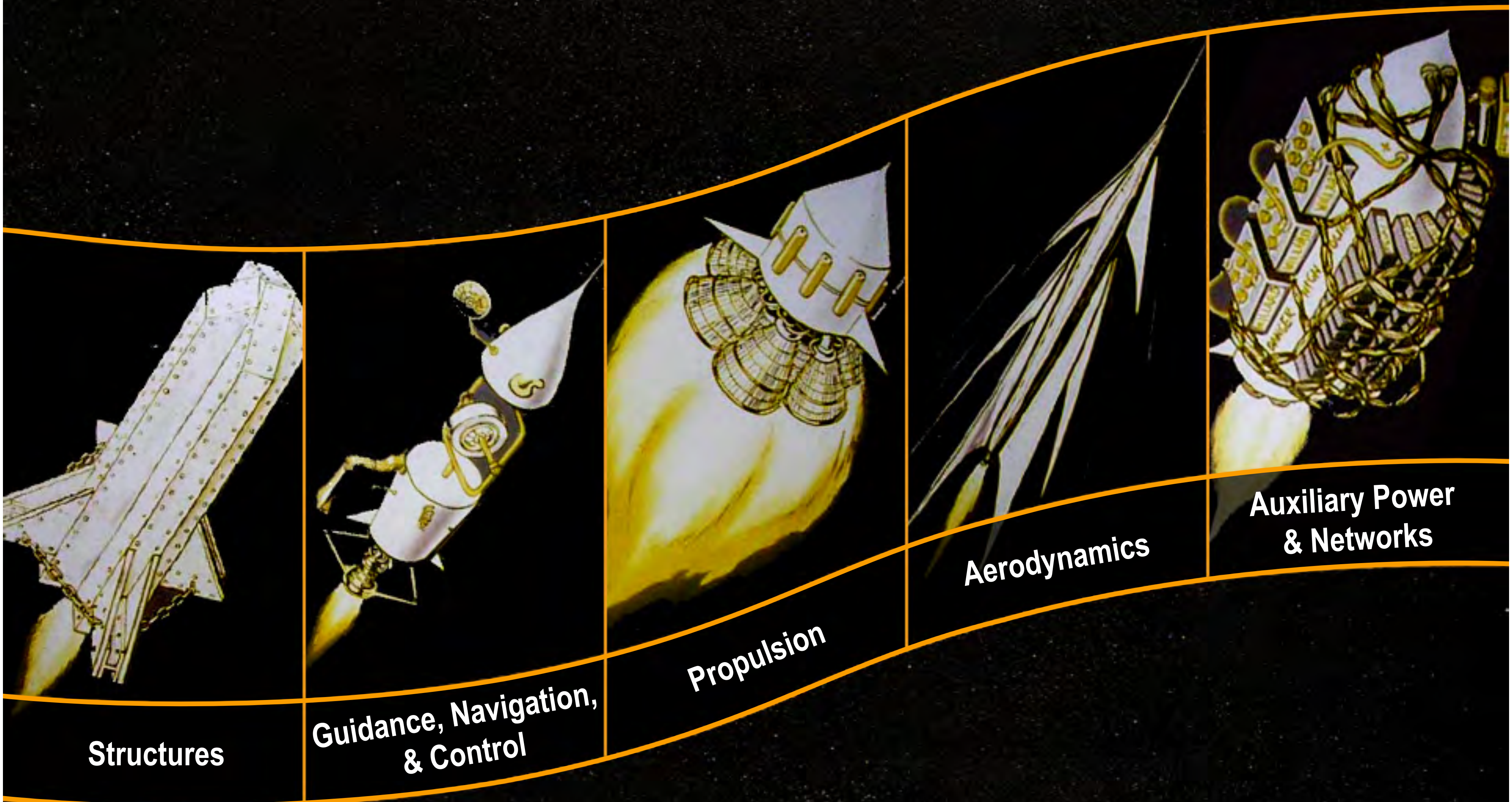
# Requirements Drive the Solution




*A designer knows he has achieved perfection not when there is nothing left to add, but when there is nothing left to take away. — Antione de Saint Exupery*

# SLS Driving Objectives

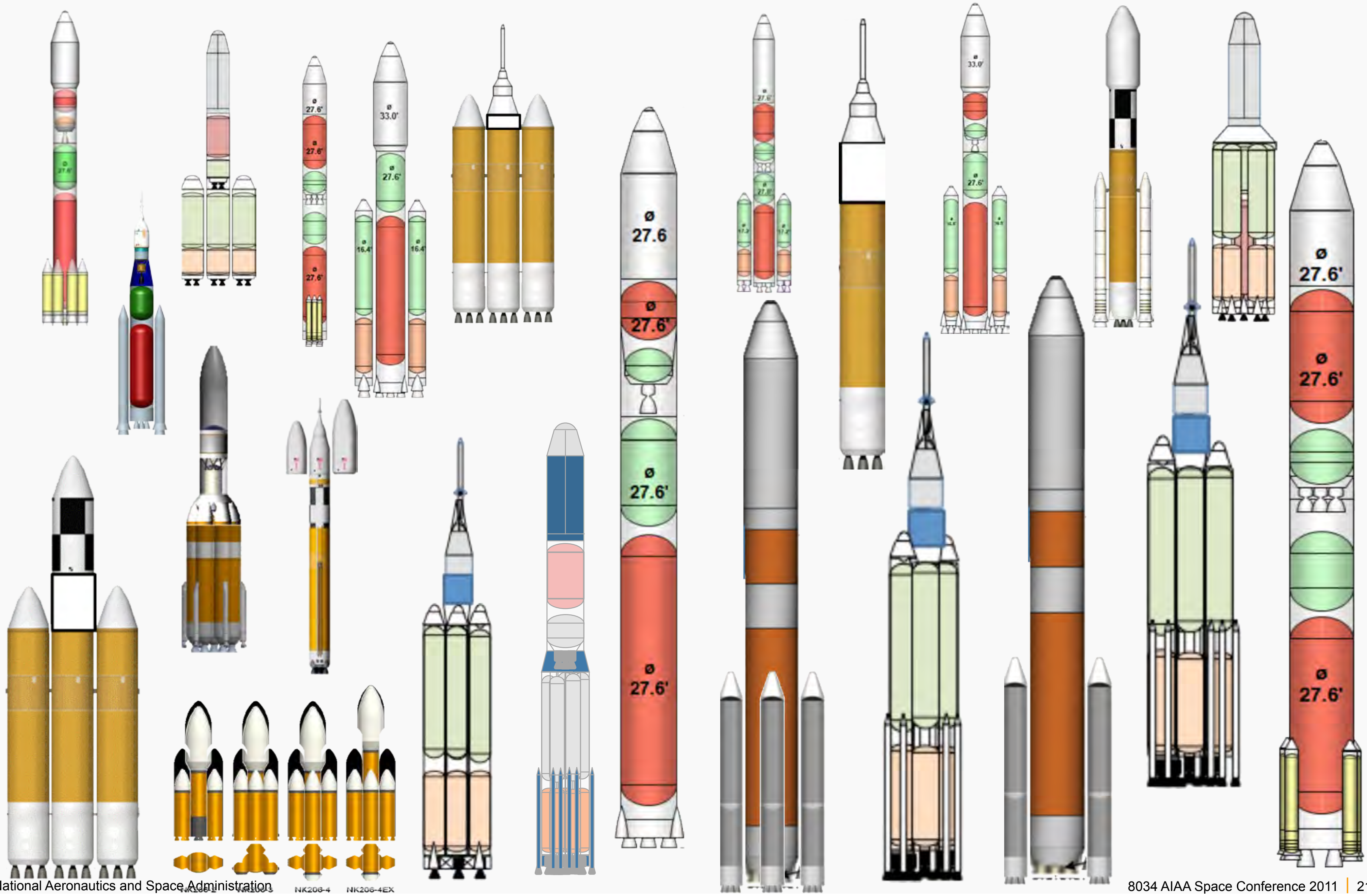
- **National Heavy-Lift Capacity**
  - 70 tonnes (t) evolvable to 130 t
  - Serves as primary transportation for MPCV and exploration missions
  - Provides back-up capability for crew/cargo to ISS
  - Offers volume for science missions and payloads of national importance
- **Safe**
  - Loss of Crew: 1/700
  - Loss of Mission: 1/100
- **Affordable**
  - Constrained budget environment, with no planned escalation
  - Maximum use of common elements and existing assets, infrastructure, and workforce
- **Near-Term Capability**
  - First flight in 2017

# SLS RAC Study Plan

- **RAC Teams Scope**
  - Team 1 – Liquid Oxygen/Liquid Hydrogen (LOX/LH2) Core Configuration with multiple evolution paths; based on Agency's Reference Design Vehicle
  - Team 2 – Large Kerosene Rocket Propellant (RP) Configuration (large diameter tanks) with multiple engine options, including NASA/U.S. Air Force (USAF) common engine (reference May/June 2010 joint study)
  - Team 3 – Modular RP Configuration (smaller diameter tanks) with multiple engine options, including NASA/USAF common engine
  - Team 4 – Focused on generic affordability challenges and opportunities (white paper released)
- **Three major objectives**
  - Incorporate ***Affordability*** into the product life cycle
  - Complete initial requirements development cycle
  - Incorporate and demonstrate lean systems engineering and integration
- **Collaboration**
  - Teams and/or Steering Committee included reps from 9 of 10 Field Centers

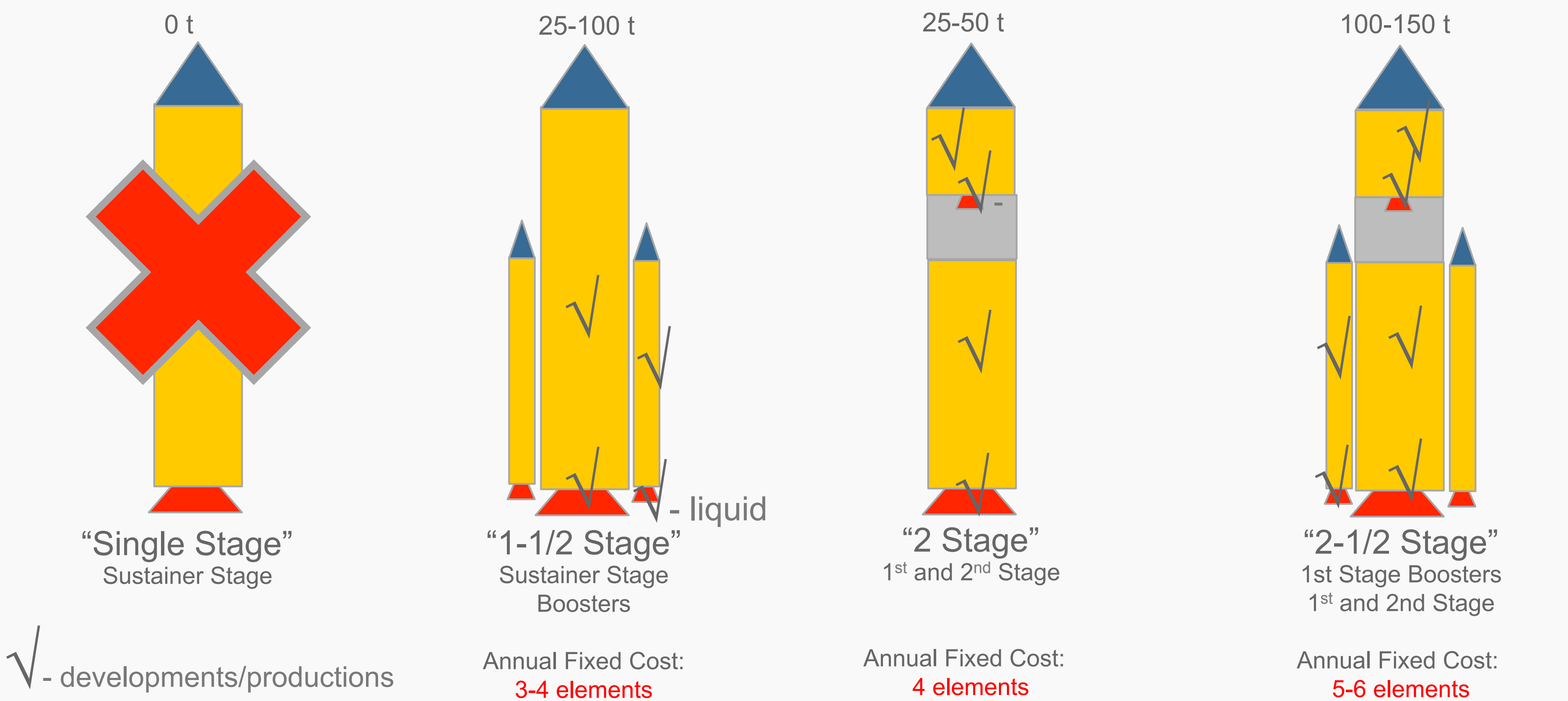
**Engineering Trade Studies and Business Case Analyses**

# A Few of Many Solutions Considered



# Affordability Is Directly Proportional to System Simplicity

- **Multiple architectures were considered to achieve optimum balance of cost, simplicity, and performance**
  - Single-stage-to-orbit is not feasible for heavy-lift systems using chemical propulsion
  - Multiple stages are required
    - More stages equals more payload capability, albeit at a greater cost
    - Must balance number of stages against cost, schedule, and payload requirements
    - Stages and engines costs can be minimized by phasing development costs



# SLS Point of Departure (POD) Initial Concept

- **Core Stage**
  - 27.5-foot (8.4-meter) diameter
  - Liquid oxygen/liquid hydrogen (LOX/LH2) fuel (30 years of U.S. aerospace experience)
  - RS-25D/E engines (starts with Space Shuttle Main Engine inventory assets)

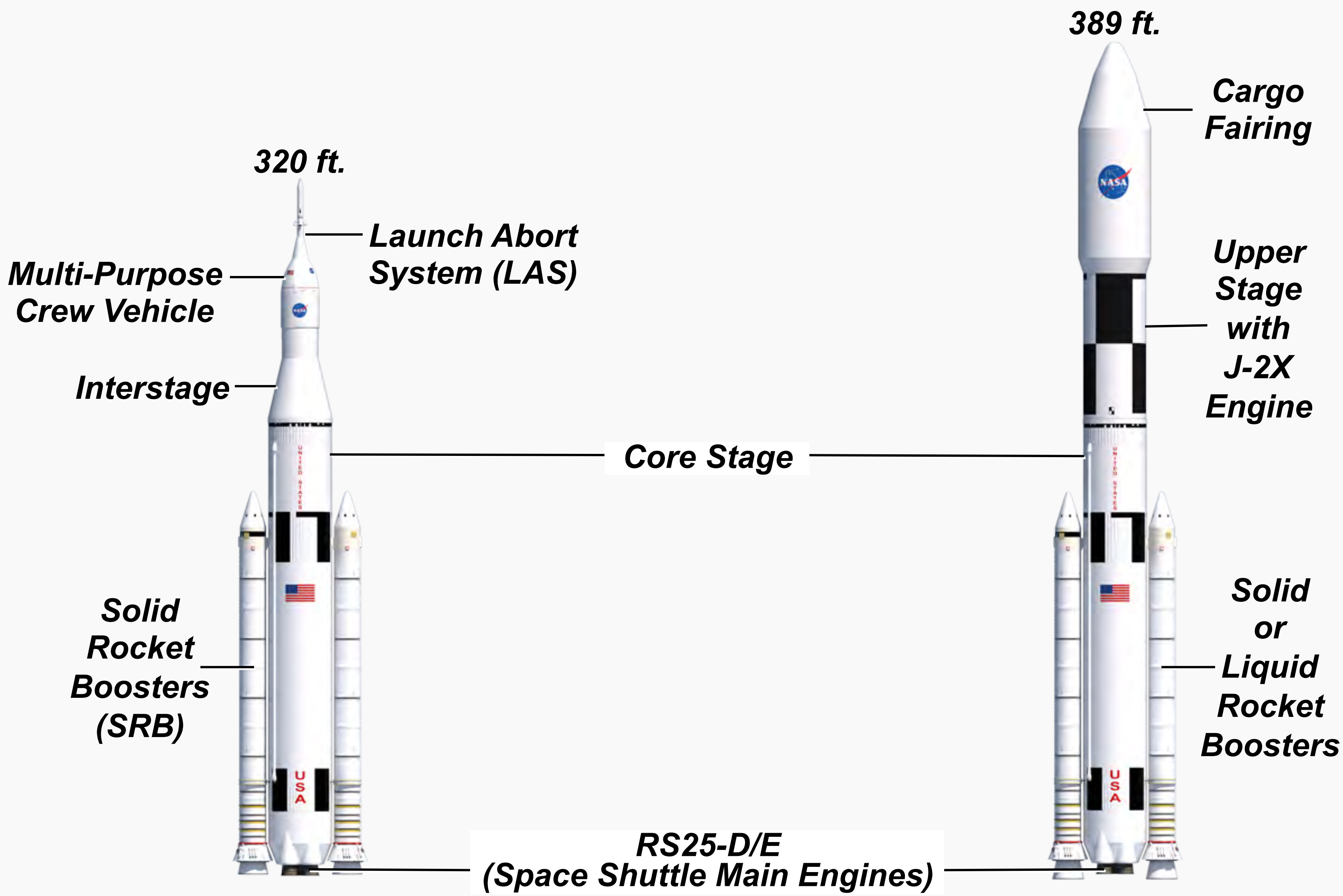
- **Commonality of Design and Manufacturing between Core Stage and Upper Stage**
  - Same diameter
  - Single facility and contractor
  - Modern manufacturing tooling and techniques

- **Boosters**
  - Initial flights are 5-segment solid rocket boosters (Ares derived)
  - Future flights will use competitively procured boosters, which may be solid or liquid

- **J-2X Upper Stage Engine**
  - Restart capability supports future in-space transfer stages trade studies
  - Metered development effort to support 130 t exploration missions

- **Vehicle development and acquisition phased to fit near-term budget constraints and schedule targets**

# Designing with the Future End in Mind: Current Point of Departure Configurations




**Common core stage and upper stage tank diameters, and common core stage engines for both configurations, supports quick-start flexibility and affordability.**

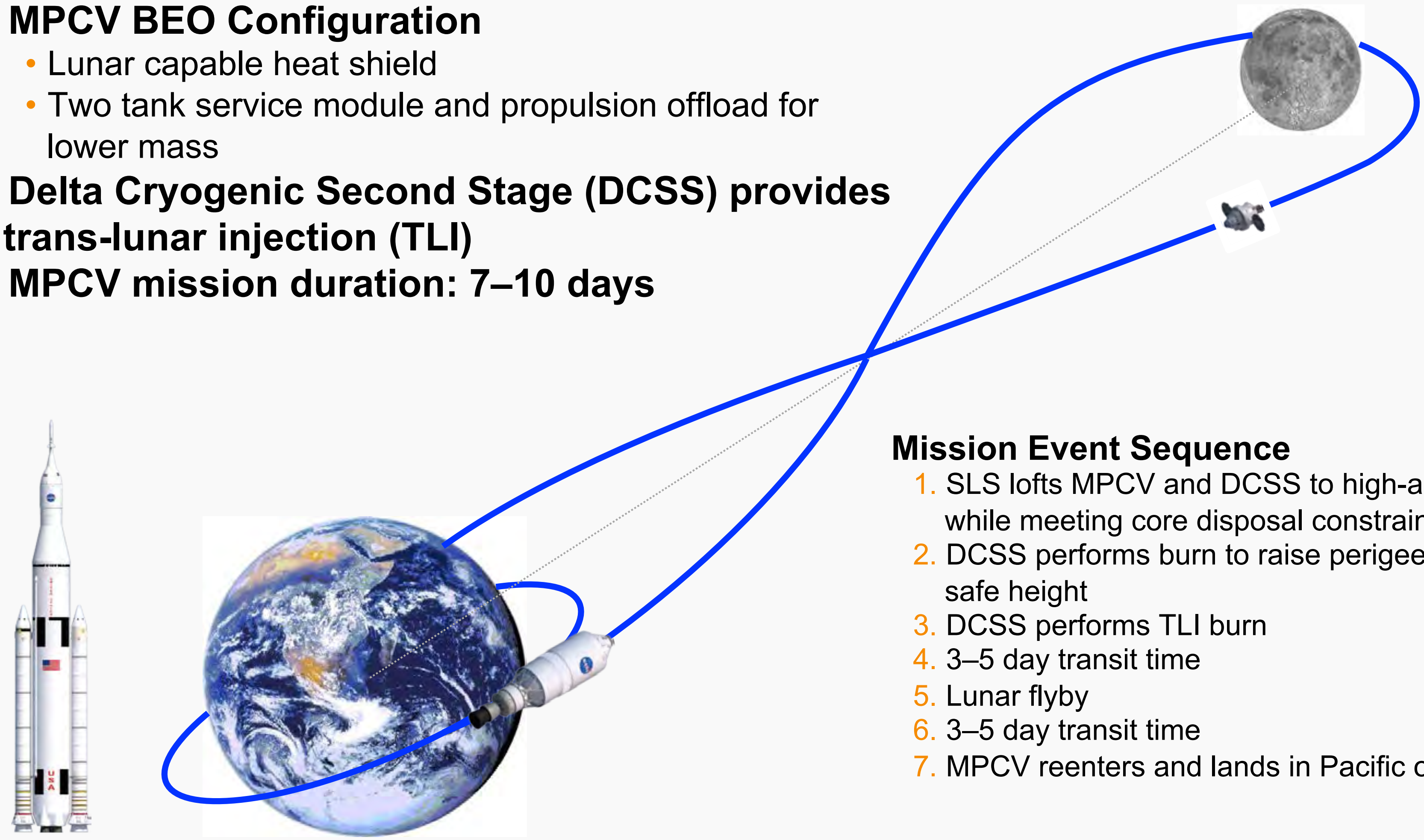
# SLS Vehicle Configuration Decision Rationale

- **Maintains U.S. leadership in LOX/LH2 technology**
  - LOX/LH2 Core Stage uses RS-25E engines; LOX/LH2 Upper Stage uses J-2X engine
  - Establishes fixed central design path, with logical use of existing strength in design and modern manufacturing approaches
  - Harnesses existing knowledge base, skills, infrastructure, workforce, and industrial base for existing state-of-the-art systems

- **Minimizes unique configurations during vehicle development**
  - Evolutionary path to 130 t allows incremental development; thus, progress will be made, even within constrained budgets
  - Allows early flight certification for MPCV
  - May be configured for MPCV or science payloads, providing flexible/modular design and system for varying launch needs
  - Gains synergy, thus reducing design, development, test, and evaluation (DDT&E) costs and schedule by building the Core Stage and Upper Stage in parallel, thereby leveraging common tooling and engine-feed components

# Notional Mission Design for First Flight in 2017
## MPCV Certification (No Crew, Lunar Flyby)

- **Objectives**
  - Demonstrate spacecraft systems performance prior to crewed flight
    - High-speed entry (~11 km/s)
    - Thermal Protection System performance
- **MPCV BEO Configuration**
  - Lunar capable heat shield
  - Two tank service module and propulsion offload for lower mass
- **Delta Cryogenic Second Stage (DCSS) provides trans-lunar injection (TLI)**
- **MPCV mission duration: 7–10 days**



**Mission Event Sequence**
1. SLS lofts MPCV and DCSS to high-apogee orbit while meeting core disposal constraints
2. DCSS performs burn to raise perigee to safe height
3. DCSS performs TLI burn
4. 3–5 day transit time
5. Lunar flyby
6. 3–5 day transit time
7. MPCV reenters and lands in Pacific ocean

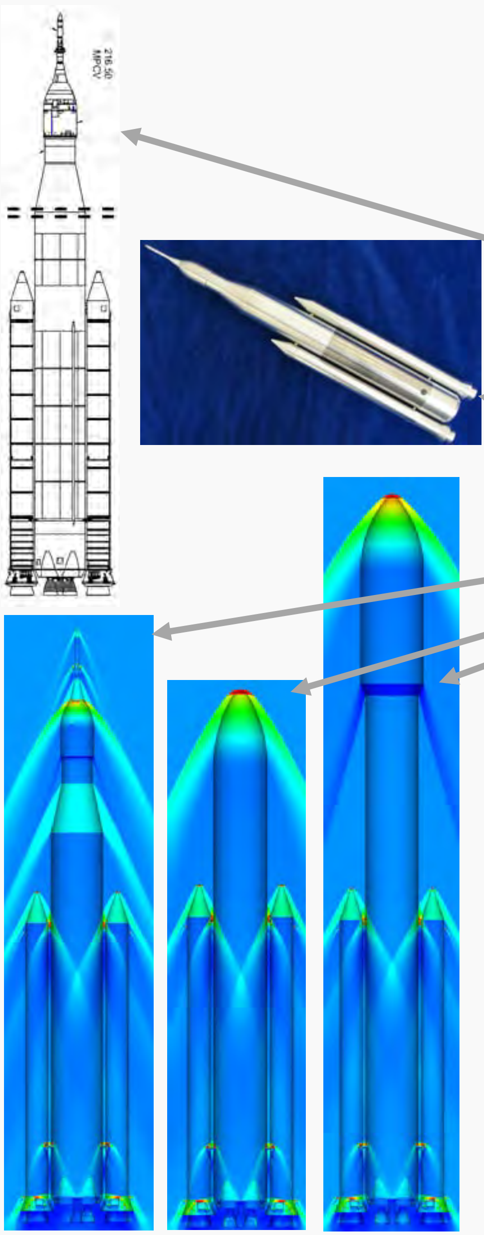
# SLS Technical Approach

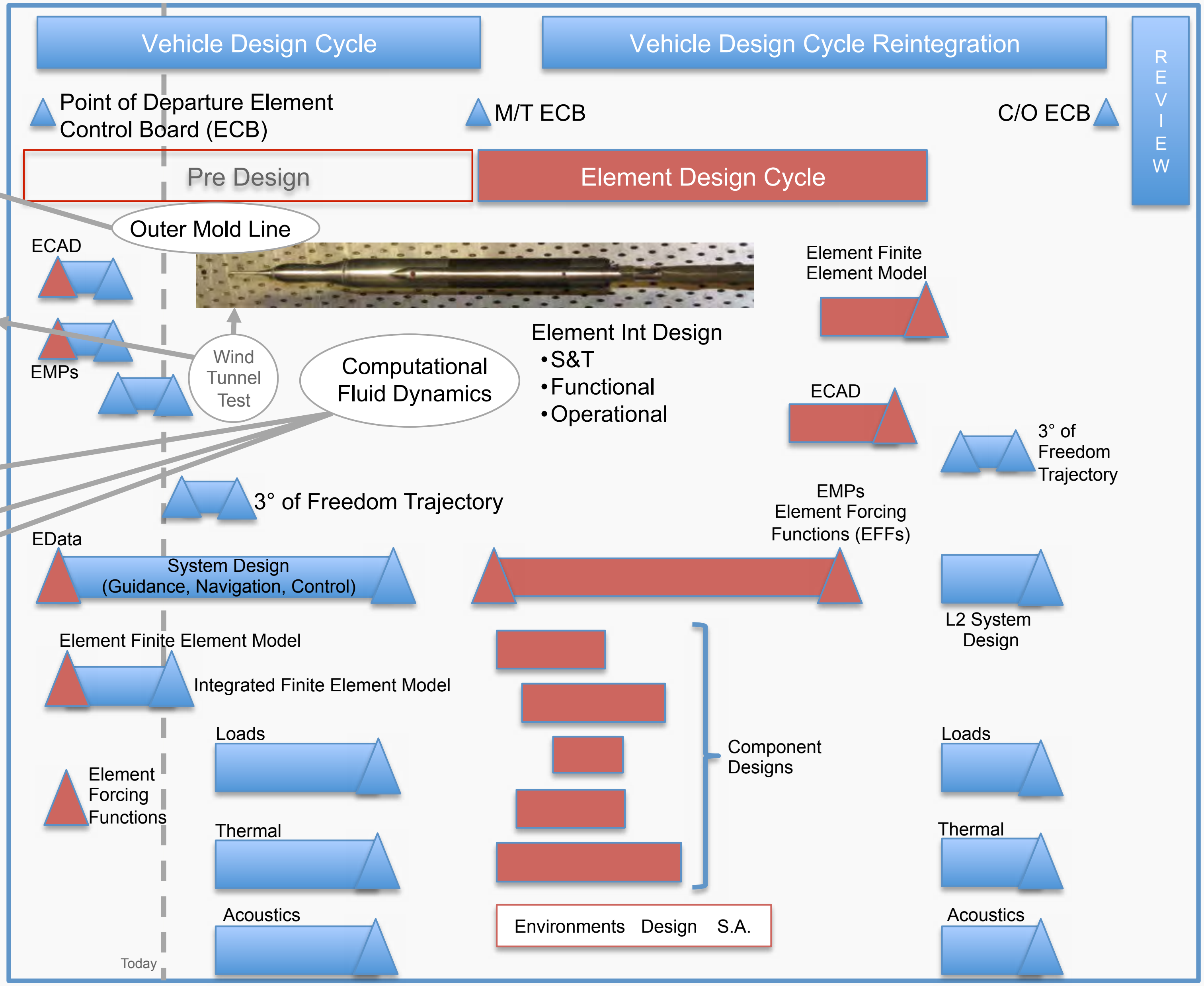
- **Risk-Based Insight/Oversight Model**
- **Lean Team**
- **Design & Construction Standards Reform**
- **Accelerated Decision Making**
  - Reduced number of boards
  - Decisions pushed down to lowest possible level
- **Interconnected Systems Engineering and Integration (SE&I) Organization**
  - Element-level horizontal integration across engineering disciplines
  - Discipline-level vertical integration across SLS Elements (stages, boosters, engines)
- **Right-Sized Document Tree**
  - Intentional reduction in number of programmatic and technical documents
  - Head-start on many SE&I products from the Requirements Analysis Cycle (RAC) process that led to the SLS Mission Concept Review (MCR)
- **Robust Design and Margin Management**
- **Hardware Commonality**
- **Performance Traded for Cost**
  - For example, less expensive but heavier material (Aluminum 2219 rather than 2195)

# Lean Systems Engineering & Integration

- **Lean SE&I Team**
  - Risk-based approach that maps personnel needs to time-phased Program needs
- **SLS SE&I is ~10% of the total budget for SLS**
- **Includes**
  - Functional Design and allocation, interface definition, and requirement and verification definition
- **SLS insight levels in line with commercial insight costs**
  - Commercial 6 – 10%
  - Government 14 – 22%

# SLS Design Analysis Cycle #1 (DAC1)





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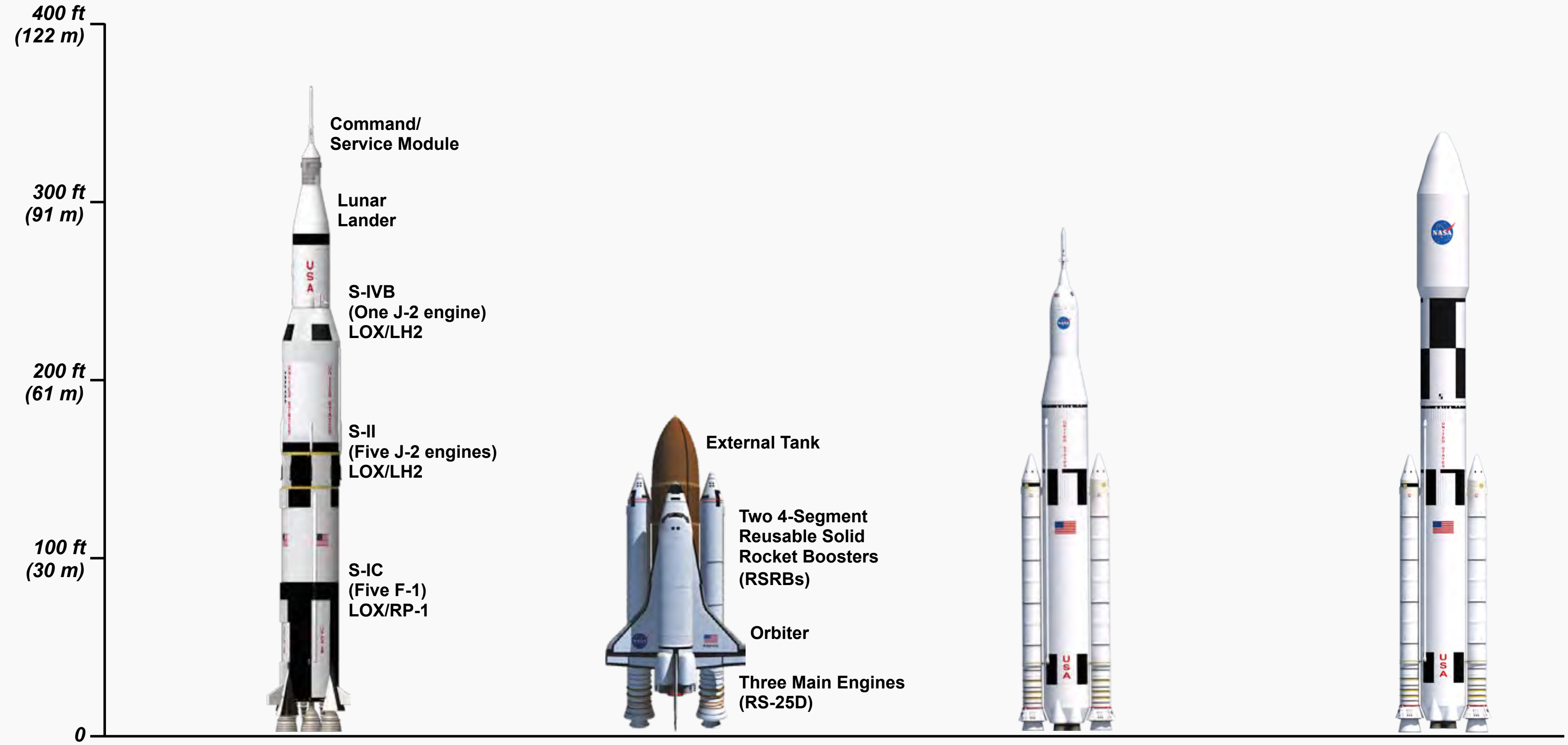
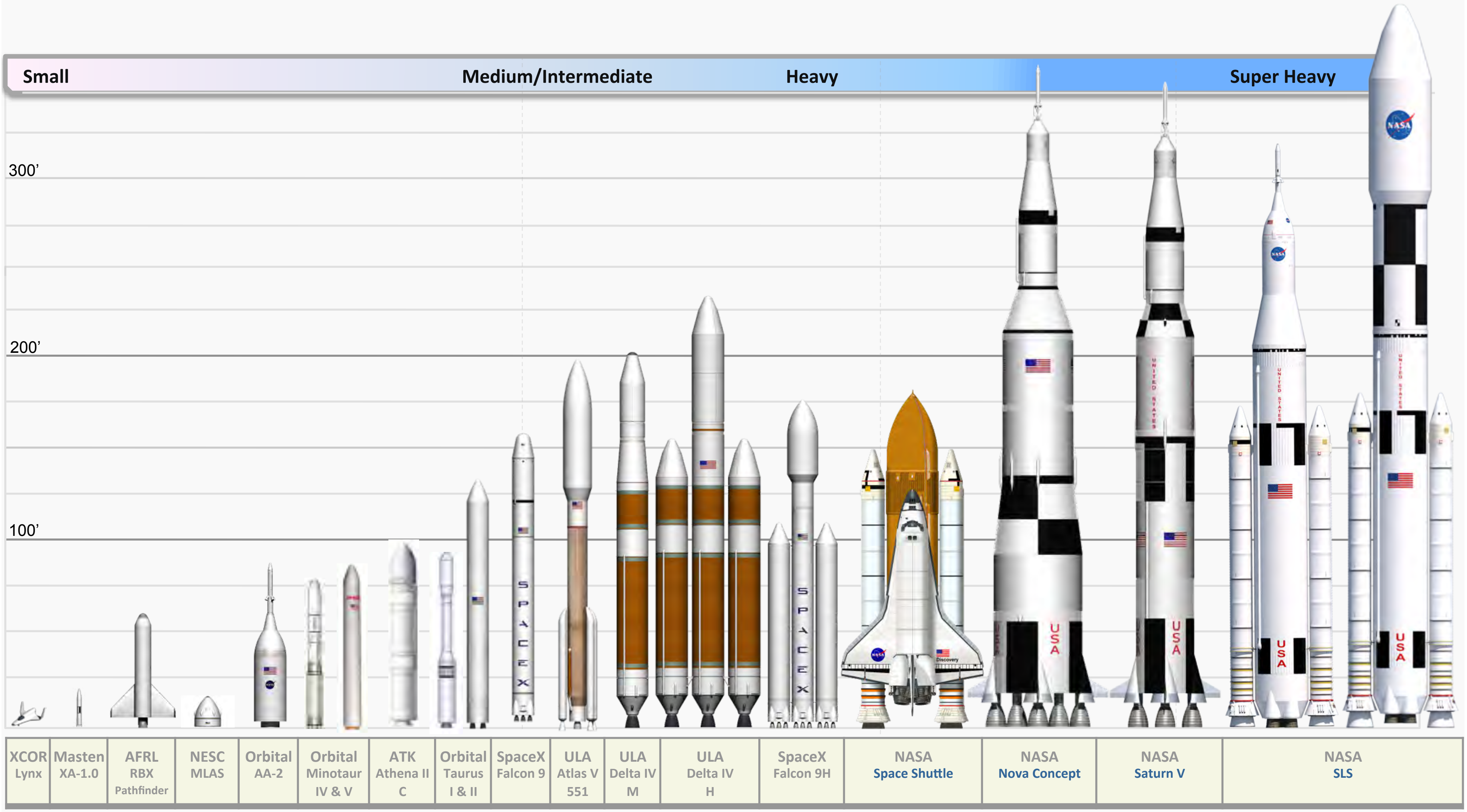
# SLS Will Be the First Exploration-Class Launch Vehicle Since the Saturn V




| | Saturn V | Space Shuttle | Space Launch System | |
|---|---|---|---|---|
| | *1967-1972* | *1981-2011* | *FIRST FLIGHT 2017* | *2021-22* |
| **Height:** | *364 ft* | *184.2 ft* | *320 ft* | *389 ft* |
| **Payload Capability to LEO:** | *118.8 metric tons (mT) (262,000 lb)* | *25.0 mT (55,000 lb)* | *70 mT (154,000 lb)* | *130 tonnes (t) (286,000 lb)* |

## *SLS Will Be the Largest, Most Capable Rocket Ever Built*

# Spectrum of United States Launch Vehicles




4/8/2011 21st CGSP

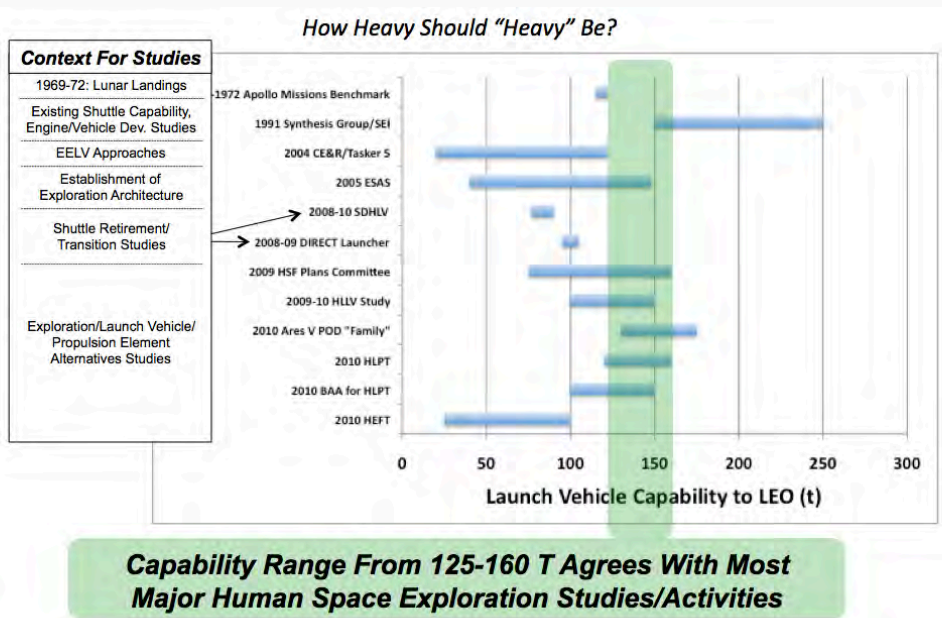
## *Sample of Proposed and Fielded Systems*

# SLS Is a National Capability

## SLS Enables Human Missions Beyond Earth's Orbit

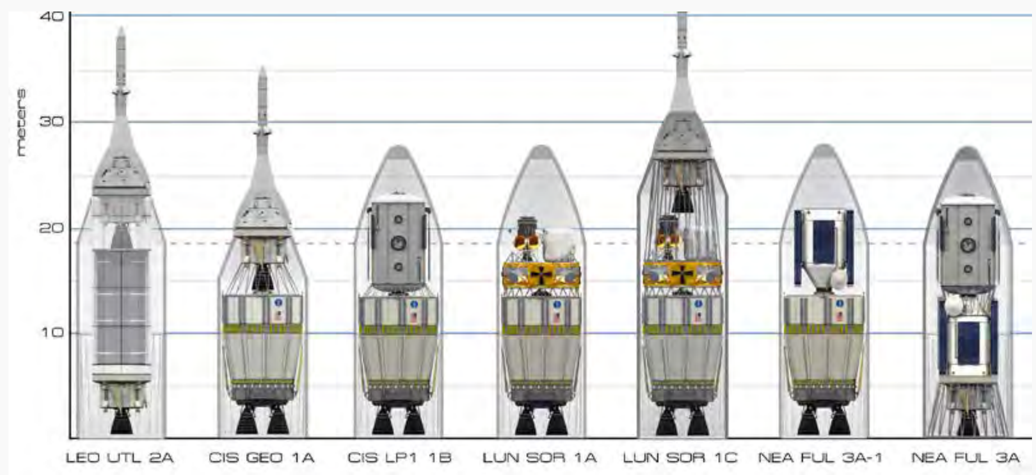
- **Very Large Payload Diameters: 8.5–12 m**
  - BEO missions require 8 m to 10 m diameter
  - Mars missions drive to diameters 10 m and larger, and increased heights above 22 m
- **Large Mass Requirements**
  - Maintains reasonable number of launches per mission
  - Simplifies on-orbit operations
  - Maximize mission reliability

**Need 125+ t capability for exploration**




## National capability for other endeavors

- Leverage BEO missions investment for other missions




## Heavy Lift Unique Payload Capacity

- Mars Transfer Vehicle
- Deep Space Exploration Systems
- Planetary Landers
- Human Habitats
- Great Observatories
- Space Solar Power
- Outer Planet Missions
- Department of Defense Payloads

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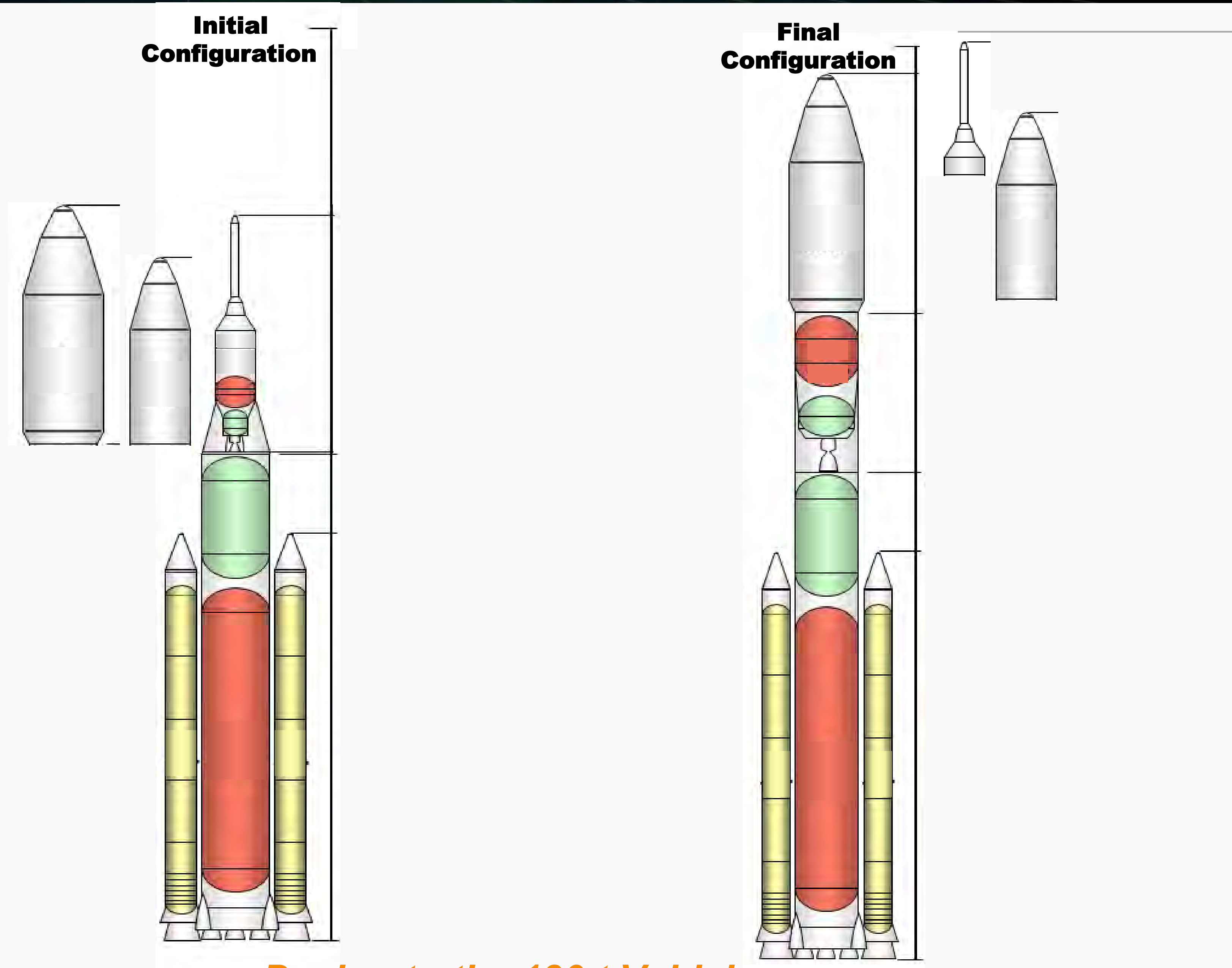
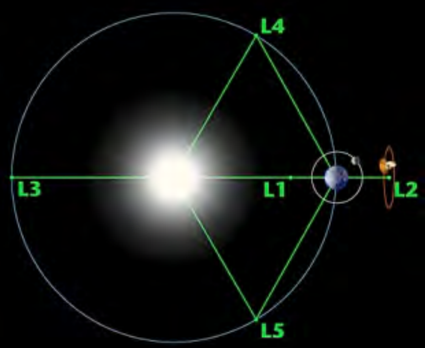
# SLS Concept for Design Analysis Cycle (DAC) 1




*Design to the 130 t Vehicle*

# SLS Is Evolvable and Flexible for Specific Exploration Mission Requirements

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# Payload Research

- It is forecasted by Paris-based Euroconsult there will be **a 51% increase in the number of satellites that will be built for launch during the next 10 years** as compared to the previous decade.

- In the next few years, DARPA would like to see **networked clusters of dozens or even hundreds of small, cheap, easily replaceable satellites working together to take the place of the large, expensive hardware currently floating around in orbit.**

- "The military is moving toward **using CubeSats more often**," says William Ostrove, space systems analyst at Forecast International.

# Candidate Payloads from National Research Council's Decadal Survey

## From *Vision & Voyages for Planetary Sciences in the Decade 2013–2022*

**Large (Exploration Class) Missions** [Cost Estimate]*

- ♦ Highest Priority: Mars Astrobiology Explorer-Cacher (MAX-C) [$3.5B]+
- ♦ Second Highest Priority: Jupiter Europa Orbiter [$4.7B]
- ♦ Third Highest Priority: Uranus Orbiter and Probe [$2.7B]#
- ♦ Enceladus Orbiter [$1.9B]
- ♦ Venus Climate Mission [$2.4B]

* Cost estimates are for the full life-cycle cost of each mission**, including the cost of the launch vehicle**, in FY2015 dollars. The committee recommends changing the New Frontiers cost cap to $1.0 billion FY2015, **excluding launch vehicle costs**.
+ This is the cost of MAX-C only, not the cost of the full Mars Sample Return campaign. Also, the estimate is for the MAX-C mission as currently conceived.
# The version without solar-electric propulsion stage.

# Candidate Payloads from Utilization Studies

- **The Single Aperture Far-Infrared Observatory (SAFIR) [Vision Mission]**
  - SAFIR is a large cryogenic space telescope envisioned as follow-on to the Spitzer Space Telescope (Spitzer) and the Herschel Space Observatory. SAFIR will provide unprecedented sensitivity in the important range between infrared wavelengths probed with the James Webb Space Telescope, and the microwave wavelengths observable with telescopes on the ground. SAFIR will explore the formation of the first stars and galaxies in the universe's distant past, and will pierce the veils of obscuring dust to reveal planetary system formation in our own Galaxy.
  - Orbit: Sun-Earth L2
  - Launch: NET 2020

- **Advanced Technology Large-Aperture Space Telescope (ATLAST) [Strategic Mission Concept Study]**
  - ATLAST is a NASA strategic mission concept study for the next generation of UVOIR space observatory. ATLAST will have a primary mirror diameter in the 8m to 16m range that will allow us to perform some of the most challenging observations to answer some of our most compelling astrophysical questions. We have identified two different telescope architectures, but with similar optical designs, that span the range in viable technologies. The architectures are a telescope with a monolithic primary mirror and two variations of a telescope with a large segmented primary mirror.
  - Orbit: Sun-Earth L2
  - Launch: Envisioned as a flagship mission of the 2025 - 2035 period

- **Stellar Imager (SI) [Vision Mission]**
  - SI is ultraviolet/optical, deep-space telescope designed to image stars similar to our sun with 0.1 milliarcsecond resolution. In addition to providing previously unattainable views of the surfaces and, via spatially-resolved asteroseismoloy, interiors of solar and other type stars, SI will reveal the inner regions and winds of active galactic nucleii (AGN) and the dynamics of many systems and processes throughout the universe.
  - Orbit: Sun-Earth L2
  - Launch: Late 2020s

- **Generation-X (Gen-X) [Strategic Mission Concept Study]**
  - Gen-X is an x-ray telescope concept to study the early universe where the first black holes, stars, and galaxies formed, as well as their evolution with cosmic time. The baseline concept calls for a partially filled 16-m diameter mirror, which folds to fit with-in a 10-m fairing.
  - Orbit: Sun-Earth L2
  - Launch: 2025 – 2035

# Candidate Payloads from Utilization Studies

- **Submillimeter Probe of the Evolution of Cosmic Structure (SPECS) [Vision Mission]**
  - SPECS is a Michelson interferometer consisting of two 4-m telescopes separated by up to 1 km to provide angular resolutions of a few tens of milliseconds of arc, similar to the Hubble Space Telescope (HST), James Webb Space Telescope (JWST), and the Atacama Large Millimeter Array (ALMA) at far-infrared and submillimeter wavelengths.
  - Orbit: Sun-Earth L2
  - Launch: Unable to Determine

- **Dark Ages Lunar Interferometer (DALI)**
  - DALI is a Moon-based radio telescope concept aimed at imaging highly-redshifted neutral hydrogen signals from the first large scale structures forming during the Universe's "Dark Ages" and "Epoch of Reionization."
  - Orbit: Lunar
  - Launch: Unable to Determine

| | SAFIR | ATLAST | SI | Gen X | SPECS | Dark Ages | Starshade |
|---|---|---|---|---|---|---|---|
| Volume (Driver Y/N) | Yes | Yes | Yes | Yes | Yes | No | Yes |
| Mass (Driver Y/N) | No | No | No | No | No | Yes | No |
| Shroud Length | No | Yes | Yes | No | No | No | Yes |
| Shroud Diameter | No | No[1] | No | Yes[2] | Yes | No | No |
| Acoustic (Driver Y/N) No = Current Shuttle Environment | No | No | No | No | No | No | No |
| Cleanliness (Driver Y/N) No = Current Shuttle Environment | No | No | No | Yes[3] | No | No | No |
| Power/Data (Driver Y/N) No = Current Shuttle Environment | No | No | No | No | No | No | No |
| Other Sensitivities | No | No | No | UNK | No | No | No |
| Enabling (ENB): Enhancing (ENH)[4] | ENH | ENB | ENH | ENB | ENH | ENB | ENH |

**UNK** = Unknown at this time

**Notes:**
[1] Assumes 16-m segmented telescope will be folded for its launch configuration
[2] Non-folded 12-m telescope
[3] X-ray and near-UV optics may need better cleanliness
[4] "Enabling" means enabling in a single launch vehicle, perhaps with much lower deployment risk. "Enhancing" means that the baseline missions can be done in a smaller launch vehicle, but Ares V offers straightforward opportunities for more ambitious versions of the mission.

Source of Table: **Workshop Report on Astronomy Enabled by Ares V** (April 26 – 27, 2008)

# Space-Based Solar Power (SBSP)

## From *Space-Based Solar Power As an Opportunity for Strategic Security* Report to the Director, National Security Space Office (NSSO) October 10, 2007

- Feasibility study for the Department of Defense to answer the following:

  *Can the United States and partners* enable *the development and deployment of a space-based solar power system within the first half of the 21st Century such that if constructed could provide affordable, clean, safe, reliable, sustainable, and expandable energy for its consumers?*

- **SBSP and lost-cost, reliable access to space are codependent**; advances in either will spur development in the other.

- SBSP is a complex challenge, but **no fundamental scientific breakthroughs are required** for it to become a reality.

- A single space solar satellite is expected to be **over 3,000 tons**.

- A necessary **prerequisite for SBSP is inexpensive and reliable access to space**.

- In order for SBSP to be cost-effective to build, operate, and maintain, the U.S. needs to develop comprehensive on-orbit space operations (e.g., on-orbit assembly, highly-efficient orbital transfer systems, and on-orbit repair, maintenance, and refueling capabilities)

- In order to **cost-effectively build** a large SBSP system, the **U.S. needs low-cost and reliable access to space**.

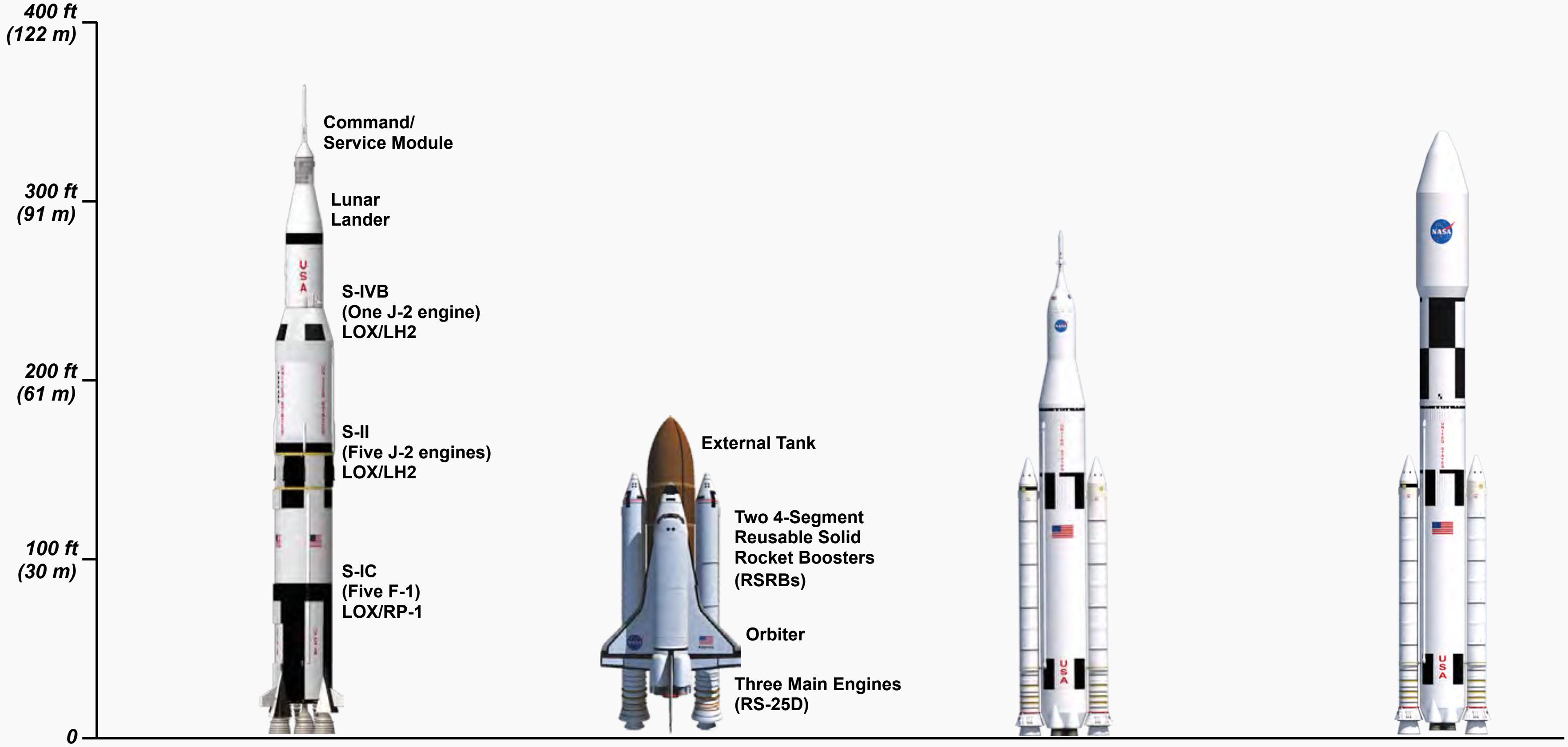
# Summary

- SLS Is a National Capability that Empowers Entirely New Exploration Missions
- SLS Program Key Tenets are Safety, Affordability, and Sustainability
- SLS Builds on a Solid Foundation of Current Capabilities to Enable a Fast Start and a Flexible Heavy-Lift Capacity for Missions of National Importance
- The SLS Payload Fairing/Shroud Will Be Sized to Support Multiple Missions and Payloads
- SLS Will Be Developed in a Phased Approach

# Agenda

- SLS Progress
  - Jody Singer, SLS Deputy Program Manager
- SLS Trade Studies and Point of Departure Configuration
  - Garry Lyles, SLS Chief Engineer
- SLS Payload Capability
  - David Beaman, SLS Spacecraft and Payload Integration Manager
- **SLS Planning**
  - **Jerry Cook, SLS Program Planning and Control Manager**

# SLS Will Be the First Exploration-Class Launch Vehicle Since the Saturn V




| | Saturn V | Space Shuttle | Space Launch System | |
|---|---|---|---|---|
| | *1967-1972* | *1981-2011* | *FIRST FLIGHT 2017* | *2021-22* |
| **Height:** | *364 ft* | *184.2 ft* | *320 ft* | *389 ft* |
| **Payload Capability to LEO:** | *118.8 metric tons (mT) (262,000 lb)* | *25.0 mT (55,000 lb)* | *70 mT (154,000 lb)* | *130 t (286,000 lb)* |

## *SLS Will Be the Largest, Most Capable Rocket Ever Built*

# Opportunities for Affordability

| Program/Project Management | Culture | Requirements/ Trades | Personnel/ Staffing |
|---|---|---|---|
| Insight and Oversight | Cost as independent variable in design trades | Clear requirements/ Rationale at the right level | Program / Project leadership |
| Planning for strategy vs. Near-term execution | Understanding implications of safety | Cost as independent variable in design trades | Right people in right roles |
| Clear and simple lines of accountability | Early identification and resolution of issues | Multiple reviews and approvals | Long-term skill maintenance / development |
| Business / contractual relationships, methods, and incentives | Delegation of authority | Industry vs. Government standards | Use of in-house capability to support programs |
| Use of modern technology | Certificate of Flight Readiness process | Cost requirements and estimates | |
| Smaller projects / Periodic achievable milestones | | | |

*Source: NASA Affordability Summit*

## *Opportunities for Change*

# Transitioning to Space Launch System

- Ares Project
- Shuttle Program
- Orion Project
- Mission Operations Project
- Extravehicular Systems Project
- Ground Operations Project

## EXPLORATION SYSTEMS DEVELOPMENT

### SPACE LAUNCH SYSTEM (SLS) PROGRAM

- Heavy Lift Launch Vehicle with an initial lift capability of 70-100t evolvable to the ultimate capability to 130t
- Primarily derived from legacy hardware
- Capability to lift the Multi-Purpose Crew Vehicle
- Capability to back up International Space Station (ISS) commercial crew & cargo delivery
- Ultimate missions beyond low-Earth orbit (LEO)

HOST CENTER: Marshall Space Flight Center, Alabama

### MULTI-PURPOSE CREW VEHICLE (MPCV) PROGRAM

- Serves as the primary crew vehicle for missions beyond LEO
- Capable of conducting regular in-space operations (rendezvous, docking, extravehicular activity) in conjunction with payloads delivered by SLS for missions beyond LEO
- Capability to be a backup system for ISS cargo and crew delivery

HOST CENTER: Johnson Space Center, Texas

### 21st CENTURY GROUND SYSTEMS PROGRAM

- Supports vehicle processing, launch operations, flight control operations, crew recovery, and return vehicle recovery

HOST CENTER: Kennedy Space Center, Florida

***Beginning With Available Resources and Technologies***

# Building on Heritage Hardware and Facilities

**J-2X Test Firing/Space Shuttle Main Engine Testing**
*Stennis Space Center*

**Payloads**
*Goddard Space Center*

**MPCV Integration**
*Johnson Research Center*

**Composite Structures**
*Glenn Research Center*

**Ground and Launch Operations**
*Kennedy Space Center*

**Physics Based Analysis**
*Ames Research Center*


**Manufacturing and Transportation**
*Michoud Assembly Facility*

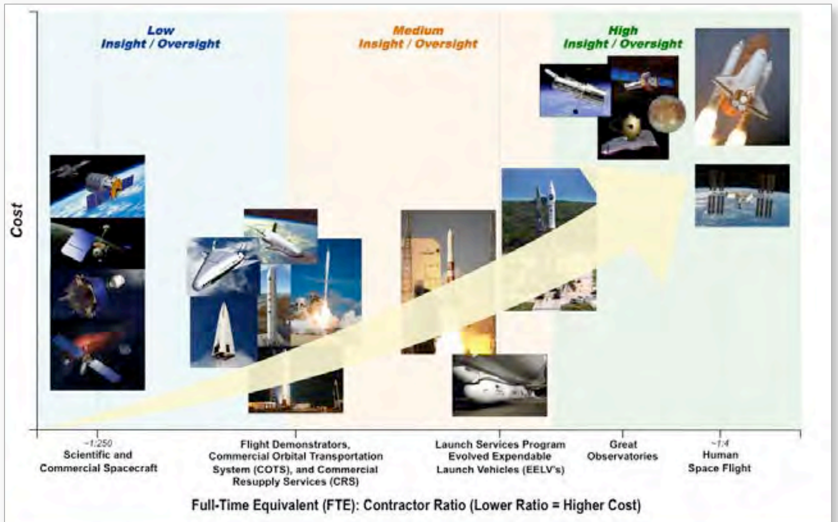
**Wind Tunnel Testing**
*Langley Research Center*

**Standing Review Team**
*Jet Propulsion Lab*

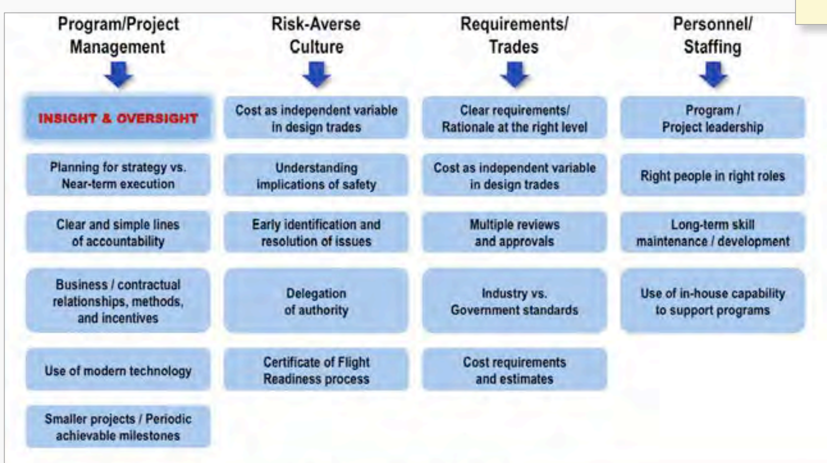
**J-2X Upper Stage Engine Injector Firing**
*Marshall Space Flight Center*

## *Smartly Selecting the Most Efficient Infrastructure*

# SLS Affordability Tenets




*Improved Human Spaceflight Affordability Required for Sustainability*

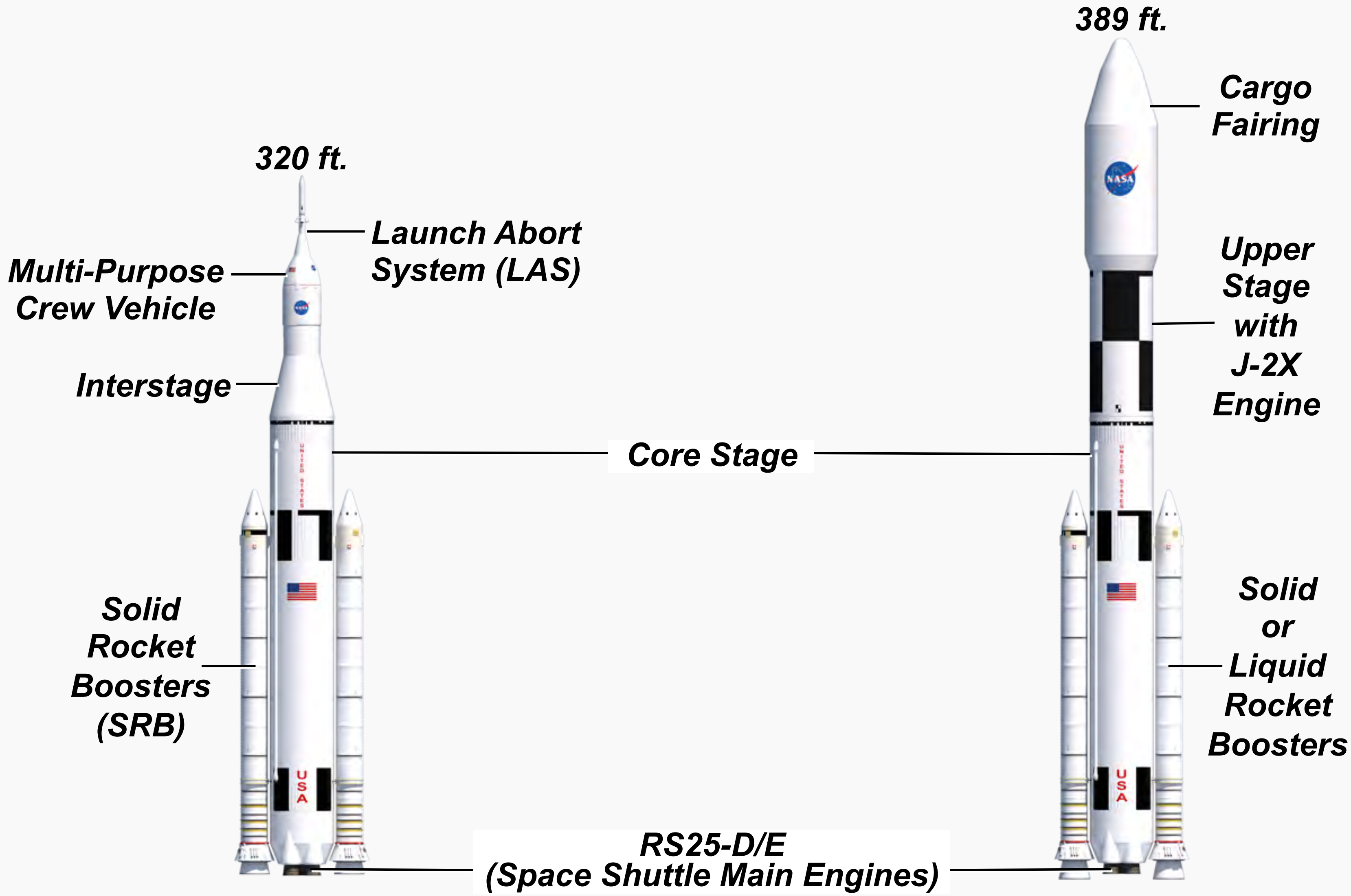



*Opportunities for Change*

- **Evolvable Development Approach**
  - Manage Within Constrained / Flat Budgets
  - Leverage Existing National Capabilities
  - Infuse New Design Solutions for Affordability
- **Robust Designs and Margins**
  - Performance Traded for Cost and Schedule
- **Risk-Informed Government Insight/ Oversight Model**
  - Insight Based On:
    - Historic Failures
    - Industry Partner Past Performance/Gaps
    - Complexity and Design Challenges
  - Judicious Oversight:
    - Discrete Oversight vs Near Continuous
    - Decisions Made Timely and Effectively
- **Right Sized Documentation and Standards**
  - Reduction in the Number of Program Documents
  - Industry Practices and Tailored NASA Standards
- **Lean, Integrated Teams with Accelerated Decision Making**
  - Simple, Clear Technical Interfaces with Contractor
  - Integrated SE&I Organization
  - Empowered Decision Makers at All Levels

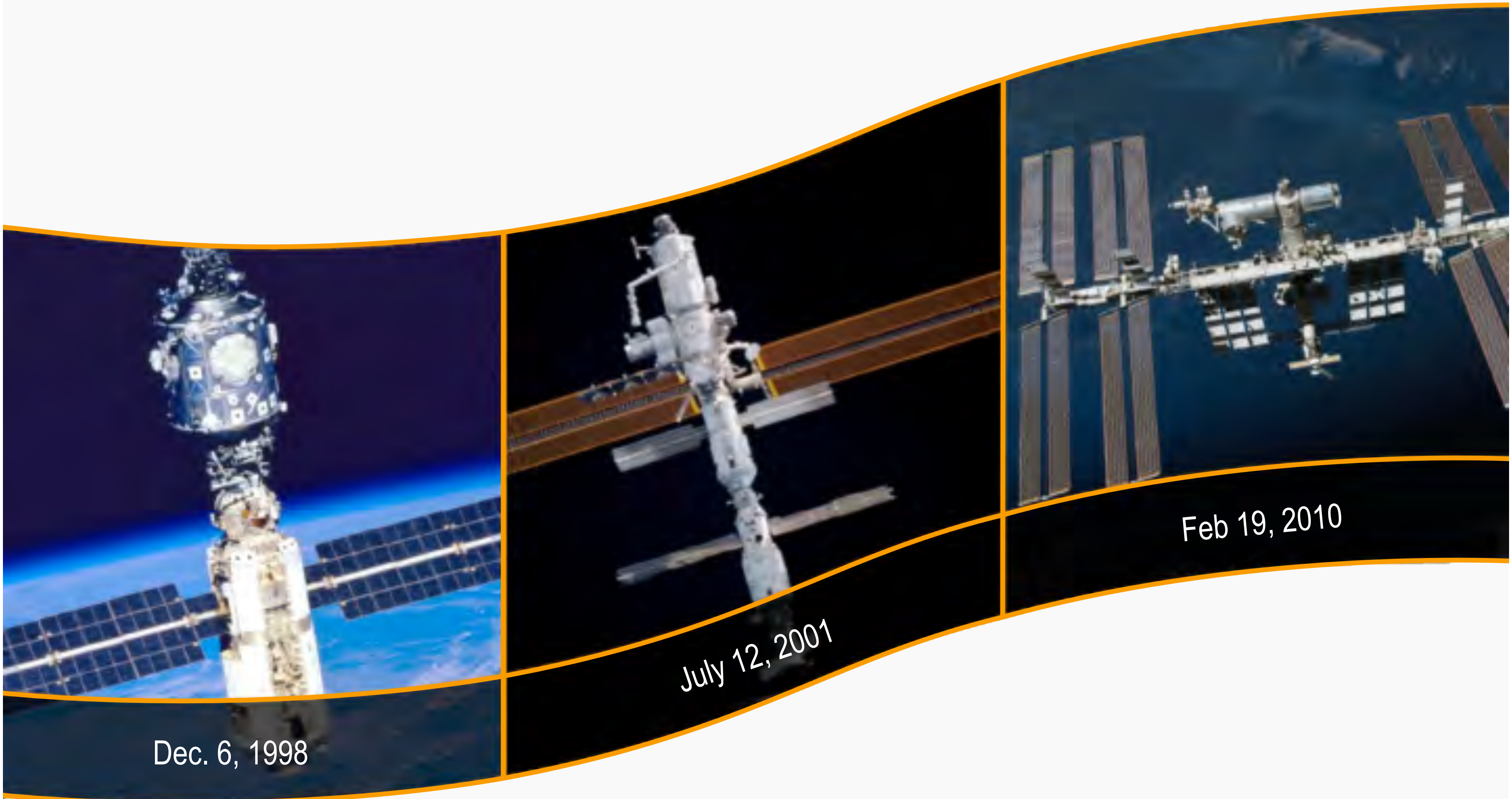
***Affordability and Sustainability, Along with Safety, are Key to Program Success***

# Designing with the Future End in Mind: Current Point of Departure Configurations




**Common core stage and upper stage tank diameters, and common core stage engines for both configurations, support quick-start flexibility and affordability.**

# Planning Programmatic Content to Deliver Incremental Capability




***Much like the International Space Station, SLS is a long-term commitment to American's future in space.***

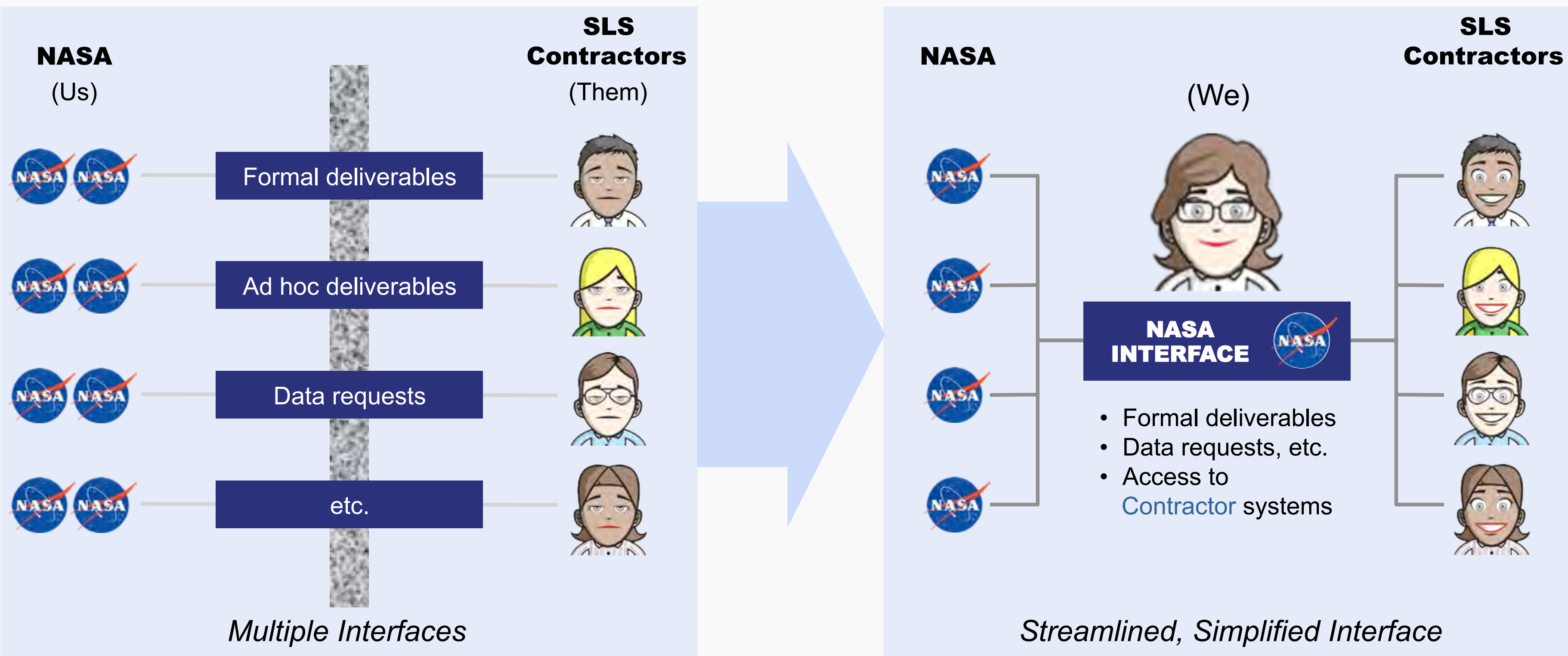
# Right-Sizing the Effort

- **Involvement by the Government/NASA should vary:**
  - Over the phase in the Program/Project Life Cycle (temporal)
  - Based upon critical factors, such as:
    - Crew safety
    - Mission success criteria
    - Hardware criticality
    - Cost
    - Schedule
    - Risks (technical, past performance, etc.)

***A Tailored Approach — One Size Does Not Fit All***

# Cost Driver: Workforce (Communication)

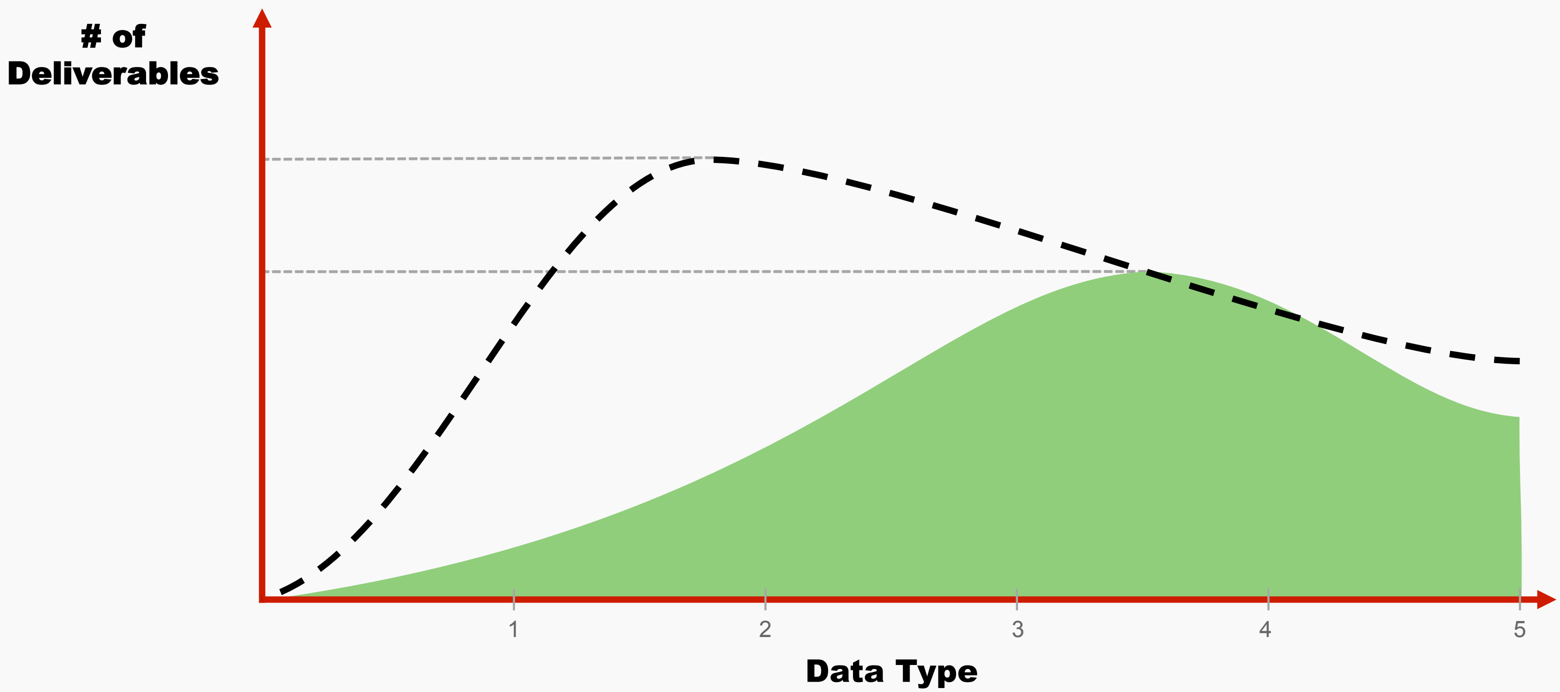
**Our Past** **Our Future**




## *Streamlined Interfaces = Streamlined Information Flow*

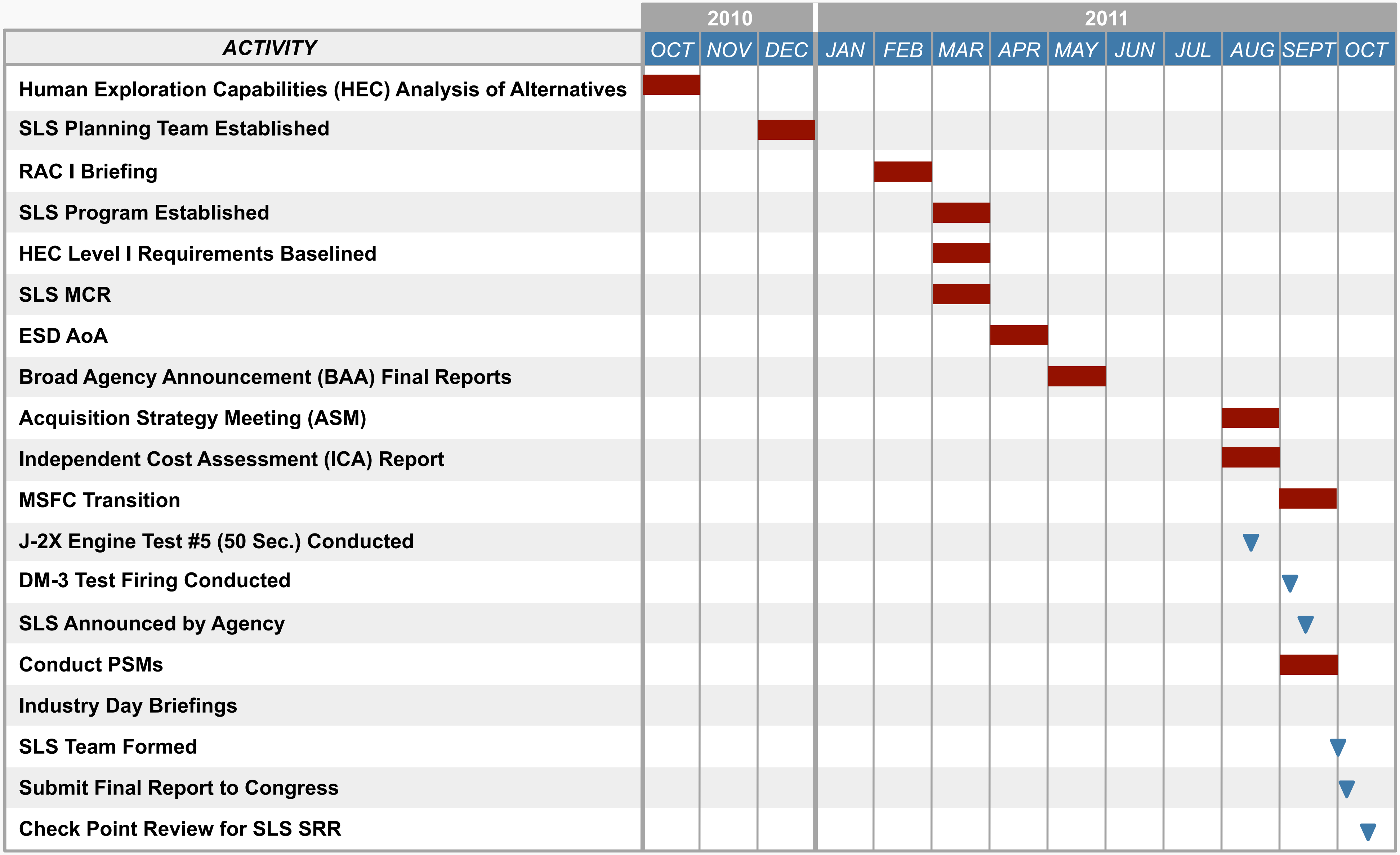
# SLS Deliverables

- Number of deliverables reduced
- More Type 3, 4 and 5's (do not require Government approval)
- Less Type 1 and 2's (require Government approval)
- Contractor's format acceptable
- Electronic access to soft copies

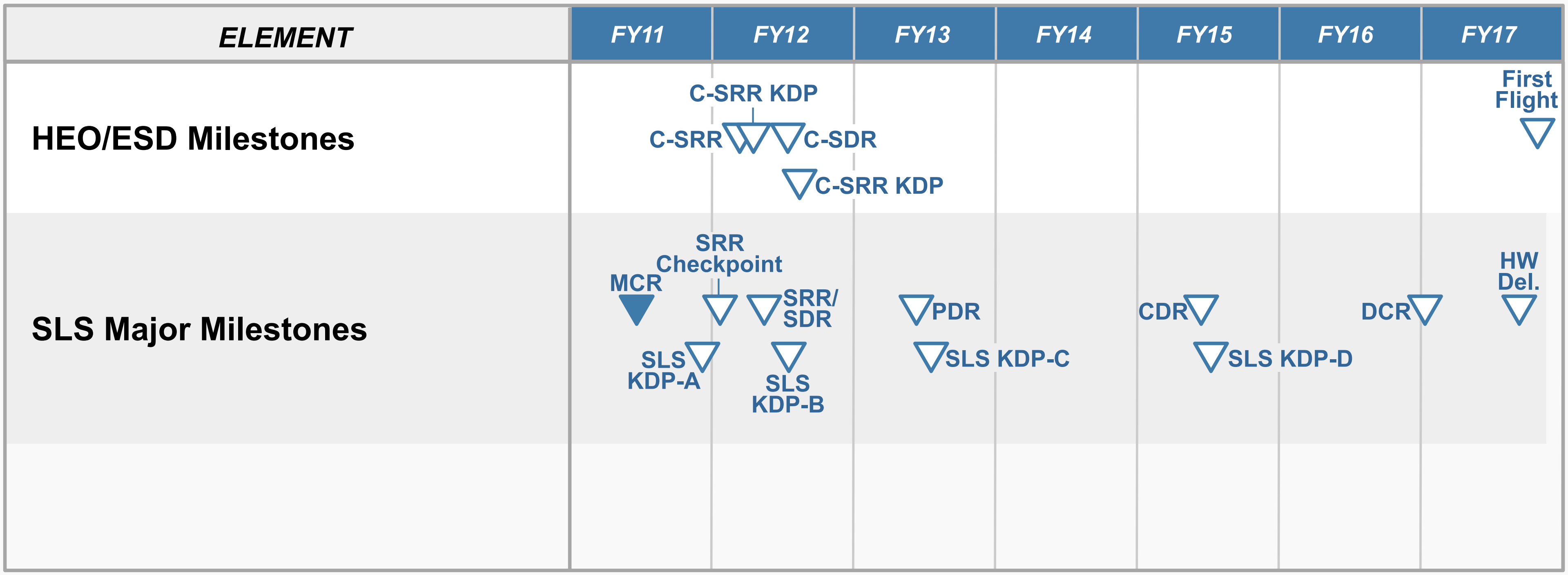



***Focuses on the Data Content and Access to the Data***

# Timeline and Near-Term Events



# SLS Top-Level Schedule




**Legend:**
*MCR – Mission Concept Review*
*C – Cross-program*
*KDP – Key Decision Point*
*SRR – System Requirements Review*
*SDR – System Definition Review*
*PDR – Preliminary Design Review*
*CDR – Critical Design Review*
*DCR – Design Certification Review*

***First Flight 2017***

# Summary

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- SLS Program Key Tenets are Safety, Affordability, and Sustainability
- SLS Builds on a Solid Foundation of Current Capabilities to Enable a Fast Start and a Flexible Heavy-Lift Capacity for Missions of National Importance
- The SLS Team has made Significant Progress
- The Road Ahead Promises to be an Exciting Journey for Current and Future Generations

## For More Information

*www.nasa.gov/sls*